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Late Holocene Geoarchaeology in the Bighorn Basin, Wyoming

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INTRODUCTION

In celebrating a career renowned for defining work on bison bone beds and Plains Paleoindian culture history, I have chosen my role in this volume to remind readers that George Frison's archaeological roots lie in the dry, dusty rockshelters of Wyoming's Bighorn Basin. When we spoke recently about his early experiences, George suggested that had he not visited Spring Creek Cave near his Ten Sleep, Wyoming, ranch during the winter of 1953, he might have never pursued the career we reflect on in this volume. As most readers know, that calling, now more than six decades in the making, led George to the most magnificent archaeological sites in the northwestern High Plains and Central Rocky Mountains—Paleoindian, Archaic, Late Prehistoric, and Historic alike. I first encountered Spring Creek Cave's perishable artifacts in the early 1990s as a University of Wyoming freshman when my fledgling self was fixed on stone tools as the sole record of past lives. The realization that perishable things survived into the present shifted my own perception of the past in a major way. My perspective shifted again later in my undergraduate education, this time toward geology as George guided me to the works of Kirk Bryan (Bryan and Ray 1940), John Moss (1951), Luna Leopold and John Miller (1954), and, of course, Vance Haynes (1968). Little did I know at the time that, while rockshelters were not central to Vance's scholarship (but see Haynes and

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Agogino 1986; Huckell and Haynes 2003), I would trace my future work directly to his legacy, too.

In this chapter I examine the late Holocene archaeological and geomorphic history of the Bighorn Basin, focusing on rockshelters and alluvial localities. As George has challenged us to think creatively about how old sites can address new problems, I use many of the sites he excavated to examine the nexus of climate change, geomorphic response, and human adaptive variability, much in keeping with the spirit of Vance's research legacy (Finley 2008). A mounting body of research considers the influences of Pacific Ocean sea surface temperatures (i.e., El Niño Southern Oscillation [ENSO] and the Pacific Decadal Oscillation [PDO]) on western North American climate variability (Gray, Graumlich, and Betancourt 2007; Mantua and Hare 2002; McCabe, Palecki, and Betancourt 2004; Moy et al. 2002; Schoennagel et al. 2005). In this study I ask what climatic conditions favor increased/decreased moisture and how do these in turn structure the dominant rockshelter sedimentation (i.e., roof fall, colluvium, and eolian sediments) and alluvial (i.e., cut-and-fill, aggradation, erosion) processes? I draw attention to patterned, synchronous eolian deposits in rockshelters as evidence of short-term (i.e., centennial scale) late Holocene drought on the eastern margin of the Central Rocky Mountains. Building on Vance's postglacial alluvial history of the northwestern High Plains (Haynes 1968), I present preliminary results of alluvial geoarchaeology at three separate localities, demonstrating that accumulation of floodplain sediments corresponds with eolian sedimentation in nearby rockshelters and, conversely, that floodplain entrenchment co-occurs with hillslope deposition in rockshelters. Floodplain erosion and hillslope deposition were common during the first two millennia of the late Holocene (ca. 5000–3000 BP) when many regional paleoclimate proxy records point to a sustained period of increased moisture. Environmental conditions were somewhat drier ca. 3000–1000 BP when floodplain sediments accumulated, providing a source for eolian sediments in rockshelters. While the geochronology is less secure in both settings, sometime after 1000 BP regional moisture conditions increased, resulting in the reentrenchment of floodplains and deposition of hillslope sediment in many rockshelters. When combined with the growing number of regional paleoclimate proxies, the rockshelter and alluvial records add to a growing understanding of biogeomorphic response to late Holocene climate variability. This paleoenvironmental framework provides a basis for understanding how past human populations living in the area responded to potential climate changes and why those responses appear the way they do in the regional archaeological record.

To meet these broad goals, I divide the following study into three sections. The first provides the necessary background, and I begin with a short narrative of Frison's work with the late Holocene archaeological record of Bighorn Basin rockshelters. I then provide a brief geomorphic context for Bighorn Basin rockshelters, highlighting the geologic structures and geomorphic processes controlling Late Quaternary formation processes in these sites. My goal in the second section is to summarize the late Holocene depositional histories of eight Bighorn Basin rockshelters and a select sample of alluvial localities. In the third section I explore connections with the regional paleoecological record and elaborate on potential linkage between ENSO/PDO, late Holocene climate variability, and prospective human response in the archaeological record. The strength of the archaeological record in this context is as a tool for understanding how we might expect the Bighorn Basin landscape to respond to present and future climate variability.

DIGGING DOWN, LOOKING WEST

The first few years of the 1950s were not an easy time for ranchers in northwest Wyoming's Bighorn Basin. What was, in hindsight, an extreme, multiyear drought (Gray et al. 2004) brought little snow to the region, giving George Frison, a local Ten Sleep, Wyoming, rancher and US Navy veteran of the Pacific Theatre, the opportunity to finally excavate Spring Creek Cave (Figure 9.1). Local landowners brought the site to his attention, knowing his curiosity about Native artifacts. Some years before, a section of the rockshelter overhang had collapsed, causing the site to begin eroding. Reports of basketry and other perishable artifacts reached George and his wife, June, and with the landowners' consent they began searching for the site together. The Bighorn Basin landscape is a deceptive one, particularly on the eastern slope of the Bighorn Mountains, where many rockshelters are found in deep canyon country. Semiarid conditions bring an average annual precipitation of 18–25 cm, most of which comes as late winter/early spring snow and rain, and temperatures vary wildly with the seasons. The sparse desert shrub, sagebrush steppe, and juniper woodlands of the basin margin and mountain foothills give way to nearly impenetrable brush in the deep, wet canyons that cut the western slope of the Bighorn Mountains (Knight 1994). George recalled a long search through this tough gorge before finding the rockshelter on the north-facing rim about 200 m above the canyon floor. With the keen eye of an avocationalist and a true scientific curiosity, George began his first excavation, sometimes with June at his side, but oftentimes alone. The result was one of the largest

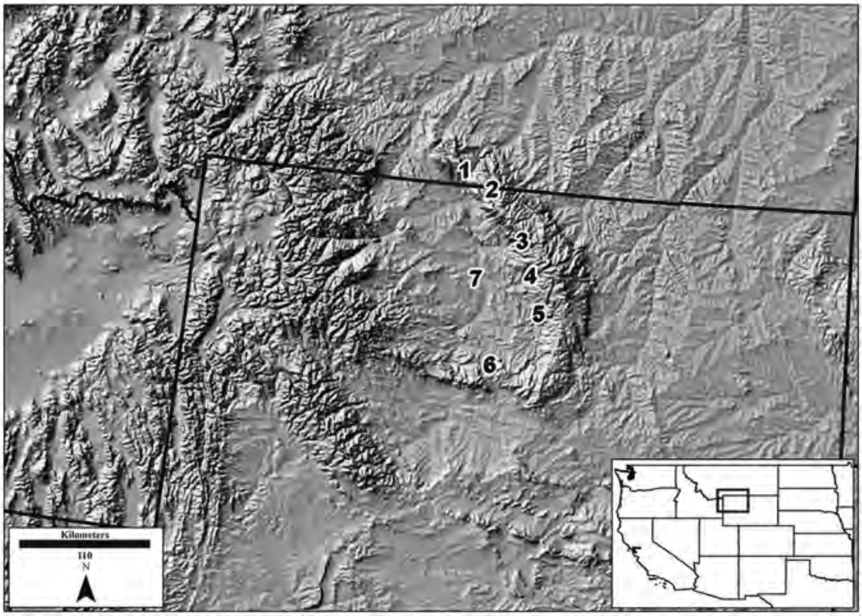

Figure 9.1. *Topographical map of the Bighorn Basin showing study sections and sites discussed in the text: 1, Bighorn Canyon–Pryor Mountain alluvial localities; 2, Little Mountain section (Eagle Shelter, Prospects Cave, Juniper Cave); 3, Black Mountain Archaeological District (Two Moon Shelter, BA Cave, Greyhound Shelter); 4, Medicine Lodge–Paintrock section (Medicine Lodge Creek Rockshelter and alluvial locality, Alm Shelter, Paintrock V); 5, Tensleep Canyon section (Spring Creek Cave, Daugherty Cave, Leigh Cave); 6, Wind River Canyon section (Wedding of the Waters Cave); 7, 10 Mile Creek alluvial localities.*

collections of Late Archaic and Late Prehistoric perishable artifacts known in the Bighorn Basin (Frison 1965). Among these artifacts were corner-notched dart points bound with sinew to their foreshafts, dart mainshafts, complete atlatls, fire-starting gear, gaming pieces, basketry fragments, cordage, leather remnants, and many other bone and wooden tools. This was one of the most unusual artifact assemblages in the Central Rocky Mountains.

At a time when trained professionals with institutional support throughout the West excavated sites such as Pictograph Cave (Mulloy 1958), the Bighorn Canyon Caves (Husted 1969), Mummy Cave (Husted and Edgar 2002), Danger Cave (Jennings 1957), Ventana Cave (Haury 1950), and Fort Rock Cave (Cressman 1942), George worked sometimes with June or other avocational friends of the Wyoming Archaeological Society. In 1955 his instinct led him to Leigh Cave (Frison and Huseas 1968) near the old fish hatchery in Tensleep Canyon (Figure 9.1). There, not far below the surface, George encountered yet another rare find—the carapaces of several hundred Mormon crickets (*Anabrus simplex*) and charred wild onion bulbs (*Allium* sp.) among other food remains scattered around a single fire hearth. Bits of cordage, worked wood, and leather were reminiscent of the Spring Creek Cave artifacts, although the Leigh Cave assemblage dated to the Middle Archaic period, approximately 4000 BP. During this time, George also looked to Daugherty Cave (Frison 1968) and Wedding of the Waters Cave (Frison 1962), both of which yielded similar perishable assemblages to Spring Creek and Leigh Cave. Although Daugherty Cave contained historic Crow materials and Wedding of the Waters had a late Paleoindian occupation, George saw in these unique late Holocene assemblages characteristics resembling the Great Basin desert culture (Jennings and Norbeck 1955) rather than that of the High Plains to the east. In a subsequent study of the basketry remnants from several Bighorn Basin sites, Frison, Adovasio, and Carlisle (1986) demonstrated that these artifacts belong to the eastern Great Basin basketry tradition, establishing a long-term historical connection between the two regions. Although not necessarily cast in this light (D'Azevedo 1986), the Bighorn Basin stands as the far eastern margin of the Great Basin culture area with an archaic ancestry for later Numic societies.

Shortly following his work at Spring Creek Cave, George visited William Mulloy at the University of Wyoming, himself fresh from the Pictograph Cave excavations near Billings, Montana (Mulloy 1958), who suggested that George visit Marie Wormington (Colorado Museum of Natural History) and Earl Morris (University of Colorado, Boulder). George began participating in Plains Anthropological Association meetings and became acquainted with scholars to the east such as Donald Lehmer, Preston Holder, and Waldo Wedel, who challenged him to write well and publish the results of his work. To George, these instrumental early visits with such preeminent American scholars, along with other early life experiences, sowed his many seeds of intellect. In 1962, at the age of 37, George returned to the University of Wyoming. His first peer-reviewed journal article, a research report on the Wedding of the Waters Cave excavations (Frison 1962), was published that year in *Plains Anthropologist*. While his research efforts expanded to form the body of work we now celebrate, he continued to work Bighorn Basin rockshelters through the 1970s (Figure 9.2), excavating the Medicine Lodge Creek site, first reported in a festschrift for his PhD mentor (Frison 1976; but see

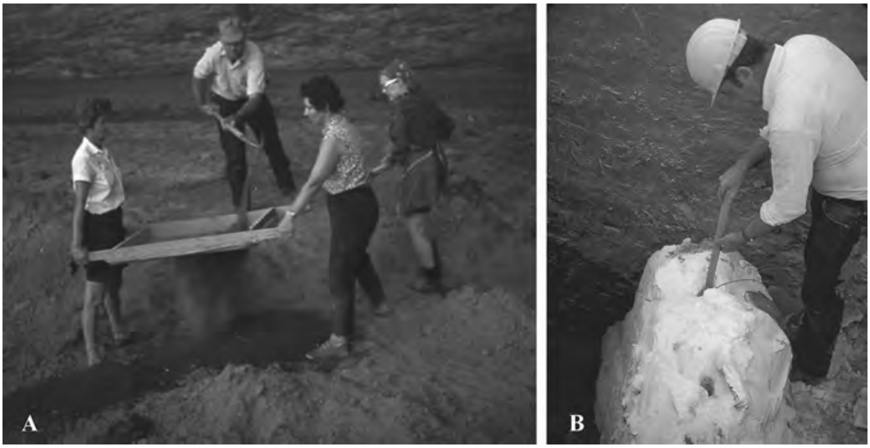

Figure 9.2. *George Frison excavating rockshelters in the Bighorn Basin: A, George working at PowWow Shelter with the "Girl Scouts" near Ten Sleep; B, George used dynamite (shown here) to remove large roof fall slabs from the excavation at Medicine Lodge Creek.*

Frison and Walker 2007), James Griffin, and producing defining works on the Late Paleoindian Foothills-Mountain Tradition (Frison 1973, 1976; Frison and Grey 1980). Yet as his collaborative network expanded to include geologists J. D. Love, Love's son, Charlie, John Albanese, and Vance Haynes, the geoarchaeology of Bighorn Basin rockshelters remained largely unexplored.

THE GEOMORPHIC SETTING OF BIGHORN BASIN ROCKSHELTERS

Beside its rich archaeology, the Bighorn Basin is a key destination for many geology field expeditions, largely due to extensive and well-exposed formations in both the basin and mountain foothills. The region's thick sequence of Late Paleozoic sedimentary rocks (Boyd 1993), namely the Madison Limestone and the Tensleep Sandstone, is important to the geomorphology of Bighorn Basin rockshelters. While I have analyzed sandstone rockshelter formation processes in alluvial and upland settings (Finley 2007, 2008), limestone rockshelters are most common and form the core of my discussion here. The Madison Limestone is a group of Mississippian carbonate rocks formed ca. 360–20 million years ago (mya) on the then tectonically passive western margin of the tropical North American continental shelf (Boyd 1993). It is one of the major cliff-forming units, exceeding 500 m thickness in parts of Montana and Wyoming, and is exposed today in nearly every deep canyon of the Central Rocky Mountains.

Rockshelters occur in two distinct geomorphic contexts within the Madison Limestone: the Madison paleokarst (Sando 1974, 1988) and an active Quaternary karst system. The Madison paleokarst formed during the early Permian ca. 300 mya when a major sea-level regression and minor continental uplift caused meteoric water to flush through the low-elevation "Madison Plain," creating an extensive paleokarst system that exists today from Montana to New Mexico. Most of the karst filled with a mixture of collapsed Madison and younger Amsden (i.e., Permian) limestone cobbles and boulders, forming a massive but weakly cemented conglomerate. Subsequent uplift and incision of the Bighorn Mountains exposed the paleokarst in many places, baring the conglomerate to physical weathering and reexposing the cavities to form rockshelters.

The active Quaternary karst system occurs throughout the Bighorn Mountains, but most notably in the Little Mountain section near Bighorn Canyon and the Trapper Creek–Medicine Lodge sections between the communities of Shell and Hyattville, respectively (Huntoon 1985; Sutherland 1976). Although the age and inception processes are debated, the best current evidence indicates that meteoric flow and karst formation began prior to 640 thousand years ago (kya) in the Little Mountain section where a thick deposit of Lava Creek B tephra, originating in the Yellowstone Caldera, occurs in Horsethief Cave (Stock, Riihimaki, Anderson 2006). Horsethief Cave itself is among the world's 40 longest known cave passages, and along a collapsed section of the system known as Trap Canyon is a series of sinkholes and rockshelters that preserve an important record of North America's Late Quaternary paleoecological and archaeological history (Chomko and Gilbert 1987; Finley 2008; Gilbert and Martin 1984). Active karst systems in the Trapper Creek–Medicine Lodge section are unique because permanent streams "sink" into underground chambers and flow for long distances along joint-controlled networks in the Madison Limestone that formed as it fractured during subsequent uplift and deformation (Huntoon 1985). Where present in the active karst, Native occupations are limited to cave mouths; the deep passages through Horsethief Cave and Trapper Creek Cave, now known as Great X, were not opened until the late 1970s and early 1980s. An underground route through the sinks of Dry Medicine Lodge Creek has never been discovered.

My study of eight limestone rockshelters (Finley 2008), six in the active karst and two in the paleokarst, compared Quaternary sedimentation patterns between the two settings. The primary geomorphic controls acting equally on sedimentation processes in both paleokarst and active karst settings include hillslope position, opening configuration (i.e., aspect, shape, size, and presence/absence of channels or pipes connecting the opening to the overlying hillslope), and the landform angle and sediment volume lying above the rockshelter. The overlying landform and opening configuration are critical to hillslope sedimentation since, first, a sediment source must be present and, second, the cliff face or shelter opening must provide a pathway for sediment transport to the deposit (Woodward and Goldberg 2001). While many overlying landforms are bare exposures of Madison Limestone, others hold relatively shallow (i.e., 30–50 cm) mantles of fine-grained Late Quaternary sediments mixed with weathered limestone cobbles (Nesser 2004). Where sediments are present on overlying hillslopes, vegetation type and abundance controls sediment mobility, which is one of the major biogeomorphic links between rockshelter formation processes and past climate change (Collcutt 1979; Farrand 2001; Woodward and Goldberg 2001). The major difference in the sedimentation process of rockshelters in paleokarst and active karst settings is in regard to roof fall deposition, which, like hillslope sediments, is a function of availability. Rockshelters in the Madison paleokarst have an abundant supply of angular gravels and cobbles from the easily weathered conglomerate fill. The walls and ceiling of active karst rockshelters weather along preexisting joints in the limestone bedrock, making roof fall in these deposits less abundant and often larger in grain size (i.e., cobbles and boulders). Rockshelters found in both settings are equally disposed to accumulation of eolian sediments originating on the margins of the sparsely vegetated Bighorn Basin. Slope position and aspect are not significant geomorphic variables in eolian sedimentation.

Two rockshelters separated by a distance of less than 3 km along Trap Canyon in the Little Mountain section (Figure 9.1) illustrate the stratigraphic and sedimentary differences between deposits formed in the two different geomorphic settings. Eagle Shelter (Chomko 1982, 1990; Finley 2008) is a small, east-facing paleokarst rockshelter with a stratified geological and archaeological record spanning more than 14,000 BP (Figure 9.3). Sediment erodes from the overlying hillslope, forming small fans on either side of the shelter opening that deliver sediment into the shelter interior. A detailed composite profile of the Eagle Shelter deposit (Figure 9.3), where all limestone clasts > 5 cm were mapped in situ, illustrates the apparent differences between the distinct sediment types. Coarse-grained hillslope sediments and roof fall accumulated regularly, and discrete, fine-grained eolian strata are interspersed throughout the sequence. Grain-size analysis quantifies these differences where hillslope

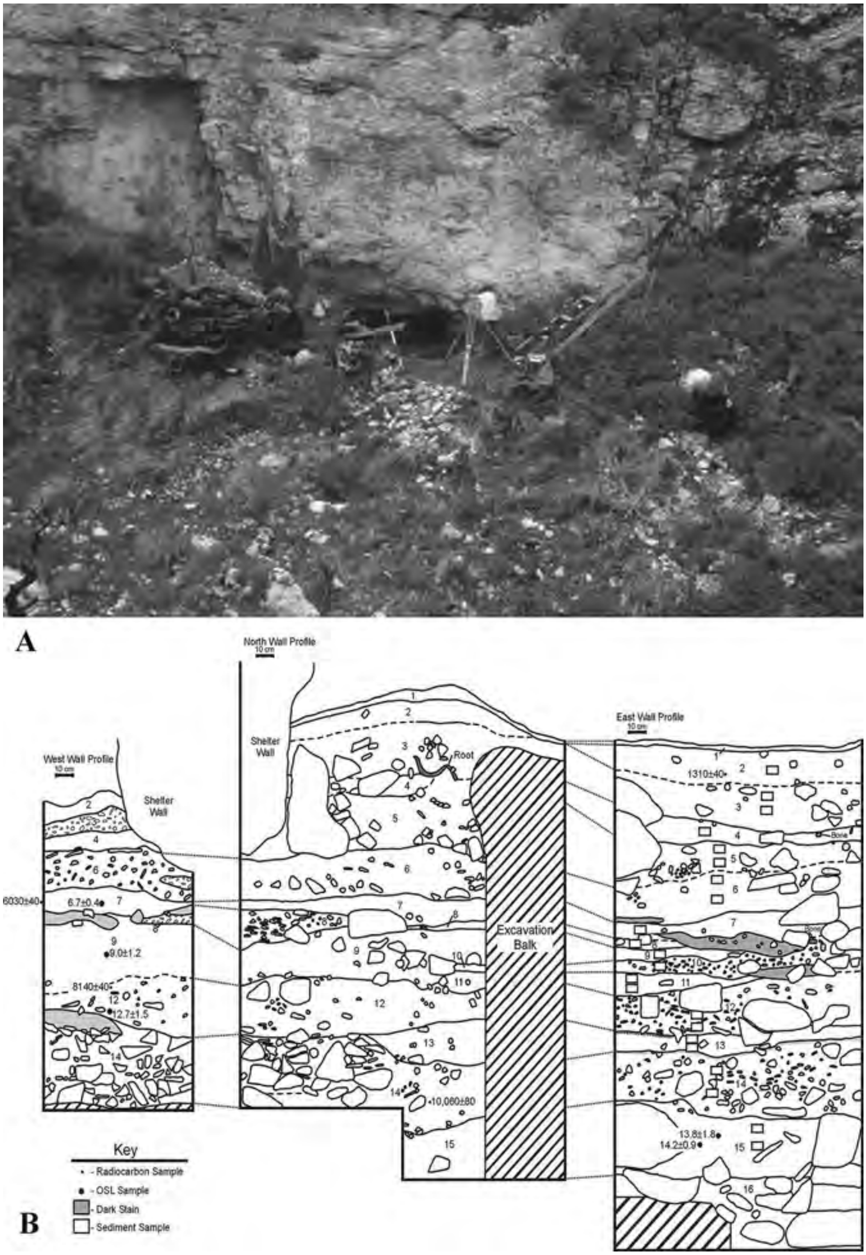

Figure 9.3. *Overview photograph of east-facing Eagle Shelter (A) and composite stratigraphic profile of sedimentary deposits (B).*

and roof fall strata have coarser mean grain size and larger proportions of silt and clay, whereas eolian sediments have finer mean grain size and a larger proportion of sand rather than silt and clay (Finley 2008). Hillslope and roof fall strata are difficult to discriminate, but differences in gravel shape and sphericity (Krumbein and Pettijohn 1938; Sneed and Folk 1958) can aid source determinations, assuming gravels originating on hillslopes will be more rounded than those originating as roof fall (Finley 2008).

As a counterpoint to Eagle Shelter's paleokarst example, Prospects Cave is a north-facing rockshelter in the active karst (Figure 9.4). The surrounding limestone bedrock is relatively smooth with no connections to the overlying landform surface, which is an exposed limestone shelf with no stored sediment. The Prospects Cave deposit has no potential to accumulate hillslope sediment, and any potential roof fall forms due to physical weathering of the limestone along existing bedrock joints (Figure 9.4). As a consequence, the stratigraphic deposit is a homogenous accumulation of eolian sediments dated with optically stimulated luminescence (OSL) to ca. 18,000 cal BP overlying a layer of roof fall deposited during the Last Glacial Maximum (LGM) ca. 21–18 kya with virtually no Holocene record (Finley 2008). Not only does Prospects Cave contrast to Eagle Shelter's thick Holocene sequence, but it also illustrates the great degree of stratigraphic variability over relatively small distances. Juniper Cave, another nearby active karst rockshelter with similar opening aspect and configuration, has the same LGM roof fall deposit, but rather than a thick eolian stratum, the deposit is an accumulation of late Pleistocene and early Holocene Bighorn sheep (*Ovis canadensis*) paleofecal material (Finley 2008; Kelly et al. 2003). Taken together, rockshelters in the Little Mountain section illustrate the singularity of stratigraphic sequences that geoarchaeologists have come to expect in regional rockshelter studies.

BIGHORN BASIN GEOARCHAEOLOGY

Late Quaternary Rockshelter Formation Processes

Rockshelter sediments currently provide the longest known continuous record of regional paleoenvironmental conditions in the Bighorn Basin, which extends at least 40,000 years into the past. While I analyzed the geochronology and stratigraphy of 10 rockshelters in three separate sections of the central Bighorn Mountains (Finley 2008), my discussion here focuses on eight limestone rockshelters in paleokarst and active karst settings (Figure 9.1, Table 9.1). General field and laboratory methods included detailed stratigraphic profiling and descriptions, comprehensive radiocarbon and OSL dating, granulometry

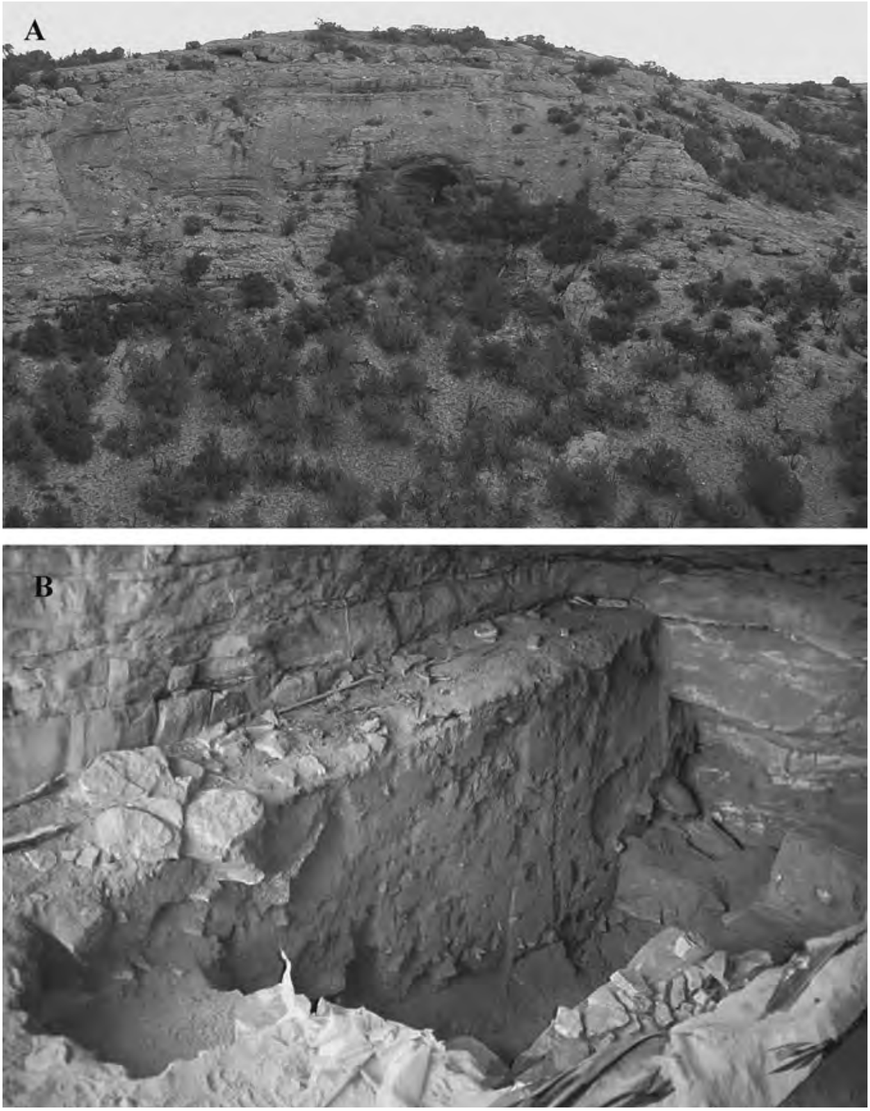

Figure 9.4. *Overview photograph of south-facing Prospects Cave (A) and massive eolian sedimentary deposit (B).*

of bulk sediment samples to determine particle-size distributions, and loss-on-ignition analysis to measure organic carbon and calcium carbonate content in sediment samples. Excluding three rockshelters in the Black Mountain

Archaeological District, which have been the focus of a long-term University of Wyoming study (Finley et al. 2005; Kornfeld 2007), either George Frison or other regional researchers excavated all of the sampled sites. Besides understanding trends in Late Quaternary formation processes, a major objective of the study was to evaluate the presence of geological deposits older than ca. 10,000 years in rockshelters and hence their potential to hold early Paleoindian archaeological materials. Rockshelters are central to understandings of early Paleoindian colonization and general settlement patterns (Kelly and Todd 1988), and prior to this work a single radiocarbon age exceeding 10,000 BP was known in association with a fragmented Folsom projectile point (Finley et al. 2005). While we can now conclude that late Pleistocene geological deposits are present in most Bighorn Basin rockshelters, early Paleoindian archaeological assemblages remain elusive. Regardless, this effort focusing on the time period ca. 12,000–10,000 years ago provided the opportunity to examine in detail many rockshelters with full Late Quaternary stratigraphic sequences.

Bighorn Basin rockshelters can be divided into three separate categories, depending on the age and completeness of the stratigraphic sequence (Table 9.1). The first category includes sites with a late Pleistocene deposit and virtually no Holocene sediments. In this category are Prospects Cave and Juniper Cave, both in the Little Mountain section described above. A third site, Last Canyon Cave (Fedorchenko et al. 2009), currently under investigation in the Pryor Mountains foothills, is similar to Prospects Cave in its thick, late Pleistocene eolian sand, which is in this case capped with a Holocene packrat midden. While sites in the first category typically bear little or no archaeology, their value as paleontological, fossil pollen, and stable isotope archives is unparalleled. The second category includes sites with fragmented stratigraphic series that are either late Pleistocene with an incomplete Holocene sequence or partial Holocene but with no late Pleistocene sequence. Four sites are in this category, including the three Black Mountain Archaeological District rockshelters and Paintrock V in the Medicine Lodge–Paint Rock section. Two Moon Shelter is mostly a late Pleistocene and early Holocene record with a nearly 5000-year unconformity separating early and late Holocene sediments. Greyhound Shelter bears a relatively homogenous fill of roof fall and hillslope sediments dating from approximately 12,000–2000 years ago with little evidence for sediment accumulation over the last two millennia. Paint Rock V is a stratified sequence of late Pleistocene to middle Holocene hillslope and eolian sediments. BA Cave is a highly stratified middle-to-late Holocene sequence of roof fall, hillslope sediments, and eolian sediments. Although excavations have not gone into the early Holocene sequence ca. 8000 years ago,

Table 9.1. Geomorphic and Stratigraphic Summary of Analyzed Rockshelters

	Geomorphic Setting	*Study Section*	*Stratigraphic Column*	*Sedimentation Process(es)*
Eagle Shelter	Paleokarst	Little Mountain	Late Pleistocene and Holocene	Hillslope, Roof Fall, Eolian
Prospects Cave	Active Karst	Little Mountain	Late Pleistocene, No Holocene	Eolian
Juniper Cave	Active Karst	Little Mountain	Late Pleistocene, Partial Holocene	Roof Fall, Biogenic
Two Moon Shelter	Non-Karst	Black Mountain	Late Pleistocene, Partial Holocene	Roof Fall, Hillslope
BA Cave	Paleokarst	Black Mountain	Late Pleistocene (?) and Holocene	Hillslope, Roof Fall, Eolian
Greyhound Shelter	Paleokarst	Black Mountain	Late Pleistocene, Partial Holocene	Roof Fall, Eolian
Alm Shelter	Paleokarst	Medicine Lodge–Paintrock Creek	Late Pleistocene and Holocene	Hillslope, Roof Fall, Eolian
Paintrock V	Non-Karst	Medicine Lodge–Paintrock Creek	Late Pleistocene, Partial Holocene	Hillslope, Roof Fall, Eolian

it is likely that BA Cave holds late Pleistocene deposits and belongs to the third category of sites, which contain complete late Pleistocene and Holocene sequences. Although there are only two sites in this category, Eagle Shelter and Alm Shelter, they are critical for linking together the first two categories into a complete sequence of Bighorn Basin rockshelter formation processes.

Key patterns emerge from the rockshelter samples that are based on variations in roof fall, hillslope, and eolian deposits (Figure 9.5). Hillslope sediments and roof fall correlate with generally moister conditions, while eolian sediments are directly linked to drought (Hanson, Mason, and Goble 2004; Parsons, Wainright, and Abrahams 1996; Woodhouse and Overpeck 1998). Depositional patterns are evidence of millennial- and centennial-scale climate change following the LGM. Millennial-scale trends include relatively dry conditions following the LGM (18,000–13,000 BP) with colder conditions producing large roof fall in most rockshelters. Moisture increased during the late glacial (13,000–10,000 BP), carrying hillslope sediments into many of the analyzed rockshelters. The 13,000 BP date is an important mark in Bighorn Basin paleoecology when both plant and faunal communities shifted to late Pleistocene steppe (Chomko and Gilbert 1987; Gilbert and Martin 1984) accompanying increased moisture. Aridity increased during the early

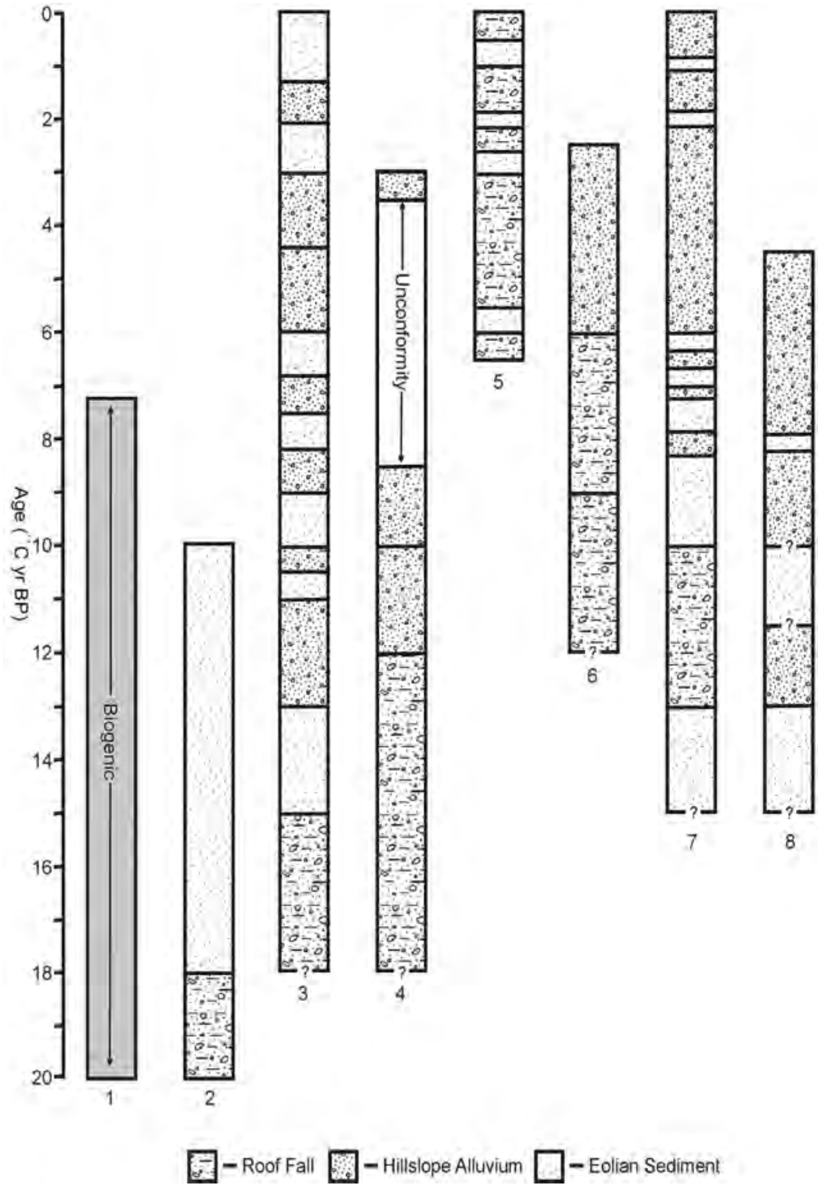

Figure 9.5. *Stratigraphic correlation chart of eight Bighorn Basin rockshelters: 1, Juniper Cave; 2, Prospects Cave; 3, Eagle Shelter; 4, Two Moon Shelter; 5, BA Cave; 6, Greyhound Shelter; 7, Alm Shelter; 8, Paintrock V. The chart demonstrates dominate trends in late Quaternary sedimentation processes.*

and middle Holocene (10,000–6000 BP), delivering eolian sediments and periodic roof fall and hillslope sediment pulses. A hillslope-dominant depositional regime accompanied the return to relatively moist conditions during the late Holocene (6000 BP to present). While the late Holocene was generally moister than the preceding millennia, synchronous eolian deposits in several rockshelters evidence centennial-scale droughts and significant climate variability. The current chronology of middle and late Holocene climate variability indicates that centennial-scale droughts centered on 6000 BP, 3000 BP, 2000 BP, and 1000 BP.

Late Holocene Alluvial History

Although the postglacial alluvial history of the Powder River Basin has received some attention (Eckerle et al. 2011; Haynes 1968; Leopold and Miller 1954), this element of Bighorn Basin geoarchaeology remains relatively unexplored. Several primary questions emerge from the rockshelter studies that inform Bighorn Basin alluvial history: Do streams in the Bighorn Basin respond to increased aridity by aggrading floodplain sediments? Conversely, does floodplain entrenchment and terrace formation correlate to periods of increased moisture? Is the late Holocene climate variability that brought droughts and eolian deposition in rockshelters of significant enough magnitude to affect the net conditions of stream dynamics? Three tributaries of the Bighorn River located in the northern, eastern, and central Bighorn Basin (Figure 9.1) provide preliminary data. Stratigraphic localities in the northern Bighorn Basin are in Bighorn Canyon, where the Bighorn River cuts deeply through Paleozoic rocks of the Bighorn Anticline before emerging onto the Montana High Plains. The Bighorn Canyon exposures are on the canyon's west side near the base of the Pryor Mountains. The eastern front of the Pryor Mountains is a steep, asymmetrical anticline of typical "trapdoor"-style faulting that creates an extreme hydraulic gradient for local tributaries of the Bighorn River (Blackstone 1940). Landforms in the canyon include benches and tables that are remnants of resistant Late Paleozoic rocks; buttes of Triassic Chugwater Formation rocks are wedged against the Pryor uplift, while massive Quaternary alluvial fans mantle many surfaces. Few permanent streams exist in this area; instead narrow, ephemeral channels are common and typically only flow after extreme rainfall events. These ephemeral streams are currently eroding their channels and forming arroyos with well-exposed stratigraphic deposits.

Five exposures in two different drainages provide data to build a preliminary depositional chronology. In many places, arroyos are entrenched 3–5 m

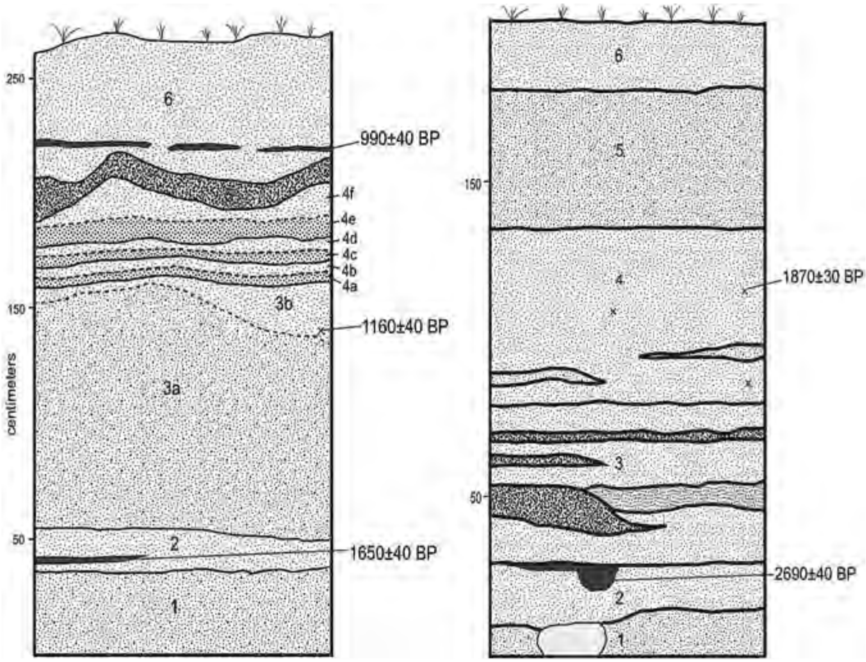

Figure 9.6. *Stratigraphic profiles of BICA10SL1 (left) and BICA10SL2 (right), two alluvial localities in the South Fork of Trail Creek, Bighorn Canyon National Recreation Area. The profiles show sandy alluvium deposited in channels formed between resistant Mesozoic rocks and gravelly Quaternary alluvial fans.*

into the narrow floodplain. Exposed deposits are typical alluvium that can be divided into three key sequences (Figure 9.6). Deeper deposits are massive sandy gravels with blade- and plate-shaped limestone clasts. Sandy gravels normally grade into gravelly sands with a predominantly Chugwater Formation (red siltstone and sandstone) lithology and smaller grain sizes. A significant decrease in grain size marks the second sequence with multiple beds of normally graded silty sand and sandy silt. These minor fining-upward sequences reflect either decreased total discharge or increased distance from the stream axis as the floodplain built. The third unit is massively bedded sandy silt with a dominant Chugwater Formation lithology. Charcoal lenses, including archaeological features, are prevalent in all of the deposits, and events at four localities are constrained by 10 AMS ages (Table 9.2). In all cases, the deepest exposed deposits are approximately 3,000 years old, while the upper sequence is less than 1,000 years old.

Table 9.2. Radiocarbon Data for Bighorn Canyon–Pryor Mountains Alluvial Localities

Sample No.	*Lab No. (Beta)*	*Material*	*13C/12C (o/oo)*	*Conventional Age*	*2-Sigma Calibrated Age Range (BP)*	*2 Sigma Calibrated Age Range (BC/AD)*
BICA09SL1-1	292787	Organic Sediment	−24.8	2540 ± 40 BP	2750–2490	BC 800–540
BICA09SL1-2	292788	Organic Sediment	−25.6	320 ± 30 BP	480–300	AD 1470–1650
BICA10SL1-1	292792	Organic Sediment	−24.2	990 ± 40 BP	960–800	AD 980–1160
BICA10SL1-2	292793	Charred Material	−22.4	1160 ± 40 BP	1180–970	AD 770–980
BICA10SL1-3	292794	Organic Sediment	−22.8	1650 ± 40 BP	1680–1420	AD 260–530
BICA10SL2-1	292795	Organic Sediment	−21.7	1920 ± 30 BP	1930–1820	AD 20–130
BICA10SL2-4	292796	Charred Material	−21.8	3010 ± 40 BP	3340–3070	BC 1390–1120
BICA10SL3-1	292797	Organic Sediment	−23.8	2250 ± 40 BP	2340–2150	BC 400–200
BICA10SL3-4	292798	Organic Sediment	−21.8	1290 ± 30 BP	1290–1170	AD 660–780
24CB4/5-1	292799	Charred Material	−23.1	90 ± 30 BP	270–0	AD 1680–1950

The second study area is in the eastern Bighorn Basin and is part of the Medicine Lodge Creek archaeological site (Figure 9.1). Medicine Lodge, one of the key regional sites that George excavated, preserves highly stratified Holocene deposits and has been particularly informative in regard to Foothills-Mountain Paleoindian Tradition occupations in the Central Rocky Mountains (Frison 1976, 1992, 1997). From a geoarchaeological perspective, the site context is unique in that it is a classic rockshelter with a distinctly alluvial geomorphic history (Finley 2007, 2008). The site is located at the confluence of the Wet and Dry Forks of Medicine Lodge Creek. Because the stream is confined here within a narrow Tensleep Formation sandstone canyon, changes in total discharge associated primarily with ephemeral flow of the Dry Fork are the driving force in channel dynamics and the archaeological site's geomorphic history. While much emphasis has been placed on early Holocene

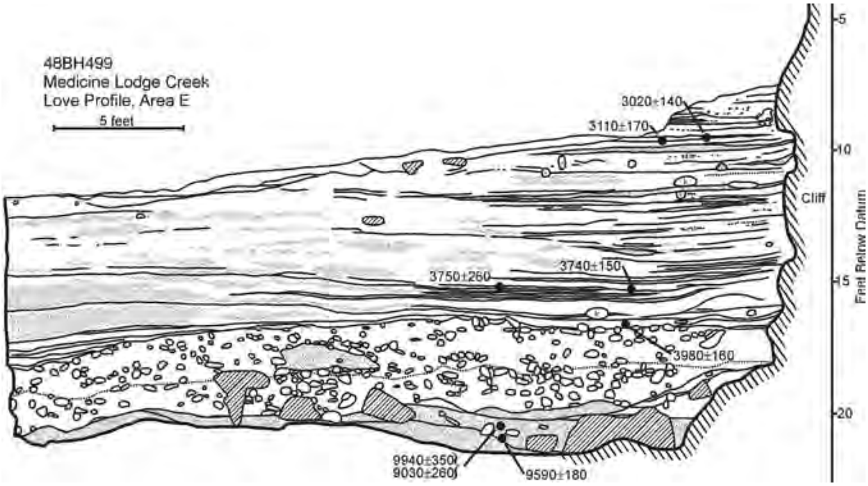

Figure 9.7. *Schematic stratigraphic profile of Medicine Lodge Creek Area E, showing a thick sequence of late Holocene alluvium overlying 9,000-year-old stream gravels. The stream channel was positioned against the cliff face before 4000 BP, removing significant early and middle Holocene deposits. After 4000 BP the floodplain rapidly accumulated sediments.*

formation processes (Frison and Walker 2007), my discussion here centers on the late Holocene deposits.

George divided the main site into two areas, with Area E containing the majority of the late Holocene archaeological and geological deposits dating from 4000 to 1500 BP. Much of the deposit is a deep sequence of graded overbank alluvium overlying a single unit of clast-supported and imbricated channel gravels (Figure 9.7). In situ archaeological materials below the channel gravels were radiocarbon dated in excess of 9000 BP, and numerous Paleoindian artifacts were found in a secondary context within the gravels. A radiocarbon date of 3980 BP from in situ archaeological deposits immediately on top of the channel deposits limits the position of the channel against the cliff face between 9000 and 4000 BP, although the 9000 BP date is a maximum age for the channel avulsion. After 4000 BP the stream migrated toward the valley axis, and graded overbank alluvium accumulated until after 1500 BP. In the early 1970s the local rancher bladed Area E, destroying deposits younger than 1500 BP, so interpretations of recent deposits are speculative. Based on exposures in other parts of the site, graded overbank alluvium transitioned into interfingering fan and stream alluvium as the stream moved toward the valley axis and the height of hillslope deposits washing over the cliff face increased.

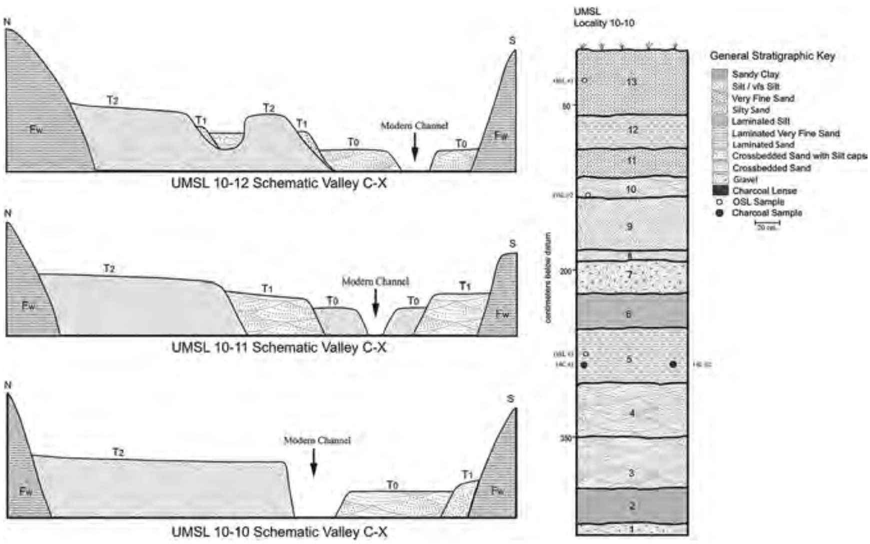

Figure 9.8. *Schematic valley cross section and typical stratigraphic profile in the 10 Mile Creek alluvial locality. Although undated, the majority of the valley fill is likely late Holocene. The T2 terrace tread may bury earlier Holocene sediments preserved at the valley margins.*

The last study area I examined is 10 Mile Creek in the central Bighorn Basin (Figure 9.1). In contrast with the Bighorn Canyon and Medicine Lodge Creek study areas, which have their sources at high elevations and have steep stream gradients, 10 Mile Creek is a discontinuous, ephemeral channel that heads in the badlands of the central basin at an elevation of less than 2,000 m (~6,500 ft). 10 Mile Creek has a broad floodplain flanked by Eocene Willwood Formation sandstone and mudstone hillslopes, which provide most of the valley's fill. The channel is currently eroding its floodplain, creating arroyo walls that in some places exceed 10–15 m in height. I documented three stratigraphic localities in a 2 km section approximately 6 km west of the Bighorn River confluence. All deposits are typical valley fill alluvium with a basal unit of massive gravel that transitions into massive silty sand and very fine sand with regular beds of laminated and cross-bedded sands (Figure 9.8). All deposits are relatively loose and pedogenically unmodified. Given the relative aridity and sparse vegetation of the central Bighorn Basin, one would not necessarily expect to see A horizons developing as Fluvents (Birkeland 1999; Reider 1990); however, no significant accumulations of clay or calcium carbonate were observed that would indicate surface stabilization and soil formation typical of Bighorn Basin environments. Likewise, the preservation of primary bedforms and abrupt stratigraphic contacts supports the interpretation of rapid floodplain aggradation and minimal pedogenesis.

As opposed to the Bighorn Canyon and Medicine Lodge Creek localities, which are rich in archaeology or datable organic deposits, no organic materials were found with which to build a preliminary depositional chronology. At best, a two-terrace landform sequence provides relative ages for the sequence. The historic floodplain existed prior to development of the arroyo. Historic structures and fences on the floodplain are buried in some places in nearly 1 m of alluvium. The first Holocene terrace can be traced through the valley by common elevation above the Historic floodplain. The riser between the first and second Holocene terraces is subtle, with less than 1 m separating the T1 and T2 terrace treads. The T2 tread can be followed to the intersection with the Willwood Formation hillslopes. Without an absolute chronology, the age of this sequence remains unknown, but given the sedimentary characteristics and lack of pedogenesis, the T1 valley fill is likely late Holocene.

CLIMATE VARIABILITY IN THE LATE HOLOCENE BIGHORN BASIN

In considering the paleoenvironmental significance of Bighorn Basin rockshelter and alluvial deposits, one key question must be considered: to what extent do patterns of landscape erosion, sedimentation, and stabilization track fluctuations in moisture conditions that alter wintertime snowpack in the mountains and delivery of late-spring and early-summer rains during critical months of the growing season? This aspect of the study integrates recent developments in climatology that specifically examine long-term fluctuations of climate systems such as ENSO and the PDO (Gray, Graumlich, and Betancourt 2007; Mantua and Hare 2002; McCabe, Palecki, and Betancourt 2004; Moy et al. 2002; Schoennagel et al. 2005). Paleoenvironmental research on fossil packrat middens and tree rings is extremely informative (Gray et al. 2003, 2004; Gray, Graumlich, and Betancourt 2007; Jackson, Lyford, and Betancourt 2002; Lyford, Betancourt, and Jackson 2002). Packrat middens highlight important Holocene temperature and precipitation trends reflected in vegetation patterns. Most importantly, the middens indicate a late Holocene "wet phase" from 4400 to 2700 BP, after which conditions became relatively dry. The tree-ring record provides an annual record of temperature and precipitation for the last 800 years and indicates that the centuries surrounding AD 1200 and AD 1600 experienced "megadroughts." Contrary to expectations and with a few multiyear droughts, the last century was one of the wettest on record. The tree-ring record builds on regional climate dynamics linking earth surface–atmosphere processes, particularly ENSO and the PDO. Specifically, the warm phase of ENSO (i.e., El Niño) and a positive PDO (i.e., warm sea surface temperatures in the eastern Pacific Ocean) bring wintertime moisture, which settles into the region as high-elevation snowpack and determines the duration of moisture into the critical late-spring and early-summer months of April through June. Conversely, the cold phase of ENSO (i.e., La Niña) and a negative PDO (i.e., cold sea surface temperatures in the eastern Pacific) results in dry winters and failed development of late-spring and early-summer storms, causing regional drought.

These interpretations correlate to the results of the rockshelter and alluvial studies and highlight the environmental dynamics controlling biogeomorphic processes. Accumulation of hillslope sediments in most rockshelters ca. 6000–5000 BP marks the late Holocene transition to increased moisture, which precedes the packrat midden "wet phase" by as much as a millennium. All alluvium documented in Bighorn Canyon ephemeral streams is less than 3,000 years old, and it is likely that during the late Holocene "wet phase," which lasted until ca. 2700 BP, ephemeral channels eroded and were perhaps scoured of older alluvium due to increased discharge. As precipitation declined approximately 3,000 years ago, stream discharge decreased and floodplains again began to build. Channel erosion in Medicine Lodge Creek ended at least 1,000 years prior to this time, and aggradation of alluvium began 4000 BP. While the 10 Mile Creek deposits are not anchored in time, based on comparisons with the other two alluvial localities, the T1 valley fill likely dates to the last 3,000–4,000 years. Decreased moisture and floodplain aggradation after 3000 BP provided a sediment source for eolian sands found in many Bighorn Basin rockshelters at ca. 3000, 2000, and 1000 BP. While neither the packrat midden nor alluvial records are resolved enough to support an interpretation of periodic late Holocene droughts, these results are worth exploring in other paleoecological contexts. As in other parts of the American West, both climate and changing land use patterns explain the formation of the modern arroyos (Harvey and Pederson 2011). Arroyo formation likely began in the late nineteenth century with a shift from the relatively dry decades of the mid-1800s to the wet decades of the early twentieth century. Reduced vegetation cover due to decades of drought, coupled with cattle grazing, increased surface runoff and arroyo formation.

If the climatic conditions of ENSO and the PDO that control patterns in the regional tree-ring record can be projected further into the past, then it is likely that the late Holocene "wet phase" was a time when the warm phase of ENSO (i.e., El Niño) and a positive PDO were more prevalent conditions of Pacific Ocean sea surface temperatures. The overall total delivery of precipitation as either high-elevation snowpack or spring rains would have increased runoff and caused hillslope sedimentation in rockshelters erosion of stream channels. Conversely, increased aridity after 3,000 years ago may be linked to a more prevalent cold phase of ENSO (i.e., La Niña) and a negative PDO. Annual precipitation would have declined under these conditions, reducing runoff and causing streams to once again begin accumulating alluvium, providing a source of eolian sediment for rockshelters.

While these biogeomorphic linkages are tentative, they provide a more nuanced interpretation of the regional archaeological record. Recent work in the eastern Great Basin and Wyoming Basin (Byers and Broughton 2004; Byers and Smith 2007; Byers, Smith, and Broughton 2005) explores trans-Holocene relationships between regional moisture conditions, artiodactyl abundance, and human foraging efficiency. These studies demonstrate that during moister environmental conditions, artiodactyl fecundity is greater, resulting in larger numbers of animals on the landscape, higher encounter rates for human foragers, and increased artiodactyls in the archaeological record. The opposite features accompany increased aridity. Following this logic, in the Bighorn Basin we should expect a prominent warm phase of ENSO (i.e., El Niño) and/or the PDO to accompany hillslope sedimentation in rockshelters, erosion of stream channels, and an increase of artiodactyls in the archaeological record. Conversely, during a prominent cold phase of ENSO (i.e., La Niña) and/or a negative PDO, we might expect floodplain aggradation, eolian deposition in rockshelters, and decreased abundance of artiodactyls in archaeological assemblages. Carcass processing intensity (Burger, Hamilton, and Walker 2005) provides yet another extension of geoarchaeological data to zooarchaeological assemblages where "good times" (i.e., moister conditions) correlate with higher big game encounter rates and decreased carcass processing intensity, and "bad times" (i.e., drier conditions) correlate with lower encounter rates and increased processing intensity. Rowe (2014) and Bryan (2006) have explored these connections, and although an apparent lag times exists in the response of faunal communities and human foraging efficiency to climate change, diet breadth and carcass processing intensity track moisture conditions evidenced in Bighorn Basin geoarchaeological records. This case study provides a model for future zooarchaeological analysis of regional rockshelter assemblages.

CONCLUSION

After more than six decades of research in Bighorn Basin rockshelters, current studies make nuanced interpretations of the regional archaeological record that integrate paleoclimatic, geomorphic, and archaeological data into a single explanatory framework. As we face the looming and uncertain prospects of global climate change, we come to understand in greater detail the diverse conditions that drive regional climate. Equatorial and northeastern Pacific sea surface temperatures are critical to contemporary Bighorn Basin climate (Gray et al. 2003, 2004; Gray, Graumlich, and Betancourt 2007). For example, during the late spring of 2011, a strong El Niño event (i.e., warm phase of ENSO) brought more than a 200 percent average annual snowpack to the Bighorn Mountains and surrounding ranges. This resulted in record June floods on the Bighorn River and many of its tributaries that exceeded the 500-year mark. The floods also brought dynamic geomorphic changes to many rivers, causing floodplain incision, erosion, and avulsion similar to those described in this study. Yet merely one year later, a strong La Niña event (i.e., cold phase of ENSO) resulted in 20 percent of the average annual snowpack in many western mountain ranges—an order of magnitude less than the previous year. Summer temperatures soared across the continent, and while crops withered in the Midwestern fields, fires consumed forests throughout the Pacific Northwest. As this chapter was being written in December of 2012, a strong, positive (i.e., warm) PDO in the northeastern Pacific was tracking one storm front after another onto the Pacific Northwest, causing massive sediment debris flows on the hillslopes and drainages of recently burned mountain forests. We need only look to see geomorphology in action and carry these lessons into the past.

In this study we have attempted to bring recent paleoclimatic research to bear on the late Holocene geoarchaeological and archaeological history of the Bighorn Basin. Rockshelters and alluvial localities are important archives with diverse but correlative records. Both systems responded to increased late Holocene moisture but in different ways. While hillslope sediments washed into many rockshelters, stream channels were experiencing either dramatic cut-and-fill events or total erosion of middle Holocene sediments. Based on analogy with dendroclimatic reconstructions, the late Holocene "wet phase" may have been a time of prominent El Niño conditions and/or a positive PDO when wintertime snowpack and late-spring precipitation were high. In the archaeological record we might expect an increased frequency of artiodactyls in faunal assemblages, accompanied by a decline in processing intensity. While alluvial records indicate floodplain aggradation after 3000 BP, many rockshelters record a series of late Holocene centennial-scale drought with an approximate 1,000-year periodicity. Droughts in the Bighorn Basin correspond with either La Niña conditions or a negative PDO that reduces wintertime snowpack and late-spring precipitation. Under these conditions, we can hypothesize that encounter rates with artiodactyls decreased, diet breadth increased, and, when killed, artiodactyl carcasses were more intensively processed. A recent analysis of Bighorn Basin paleodemography (Kelly et al. 2013) indicates that past population dynamics fluctuated in lockstep with climatic conditions. As we look to the future of climate variability in the West, our understanding of the relationships between diverse ecological systems will improve and continue to inform our understanding of past life. Archaeological research in the Bighorn Basin will remain central to that inquiry.

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