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Holocene bison in the Great Basin, western USA

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Abstract: Bison (*Bison bison*) were widespread in the eastern and northern parts of the Great Basin (the area of internal drainage in the arid western USA) during the late Holocene, particularly after 1600 ^{14}C yr BP. However, of the four areas within the Great Basin for which there is anecdotal evidence of the historic presence of these animals, only one – south-central Oregon – has provided compelling empirical data in support of that evidence. Bison populations flourished in the area immediately surrounding the basin of Pleistocene Lake Bonneville between *c*. 1600 and 600 ^{14}C yr BP, a fluorescence that seems to have been tied to deeper northwards incursions of monsoonal storms. Once those incursions weakened, bison populations declined substantially in size. The appearance of bison in south-central Oregon after 500 ^{14}C yr BP may be a function of the increased winter moisture and cooler temperatures that marked this region during the 'Little Ice Age'.

Key words: Bison, Great Basin, biogeography, climate change, Holocene, western USA.

The Great Basin

The Great Basin (Figure 1) is an area of remarkable environmental contrasts, driven by the fact that it spans about 10° of latitude (*c*. 34.5° N–44° N) and longitude (*c*. 111° W–121° W) and by the presence of dramatic differences in relief. The region contains 33 mountain ranges whose peaks exceed 3050 m in elevation, and three with elevations over 3660 m. These ranges are generally separated by long and narrow valleys whose orientation is north–south, like that of the mountain ranges themselves. Even though many Great Basin valley floors lie at fairly high altitudes (1370–1525 m is typical), the average elevational difference between valley floor and mountain top across the central Great Basin is about 1770 m (Grayson, 1993).

In large part because the Great Basin lies in the rainshadow of the Sierra Nevada and Cascade Mountains, which block the entry of moisture-bearing Pacific westerlies, the area is also arid. Average annual precipitation is only *c*. 10 cm in the most arid of Great Basin valleys, with most valleys receiving about 20 cm/yr. This modest valley-bottom precipitation is overmatched by average annual evaporation rates, which range from about 220 cm/yr in the hottest parts of the southwestern Great Basin to about 90 cm/yr in the cooler northwestern parts of the region. The mountains have far lower average evaporation rates (*c*. 75–100 cm/yr) and much higher precipitation rates (to *c*. 80 cm/yr in the Sierra Nevada and Wasatch Range). Much of the precipitation received by these mountains falls as snow during the winter months, which then feeds the region's streams and lakes during spring and summer (Grayson, 1993). In the eastern and southern Great Basin, this source of summer moisture is augmented by the impact of monsoonal storm systems, which derive their moisture from the Gulfs of California and Mexico and enter the region from the south (Houghton, 1969)

Although the salt pans that mark some Great Basin valley bottoms lack vegetation, most are covered to some degree by grasses and such xeric-adapted shrubs as big sagebrush (*Artemisia tridentata*), saltbushes (*Atriplex* spp.) and, to the south, creosote bush (*Larrea divaricata*) and blackbrush (*Coleogyne ramosissima*). Throughout much of the Great Basin, mountain flanks are covered by woodlands composed of singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*), with higher elevations supporting a variety of subalpine conifers, including limber pine (*P. flexilis*), bristlecone pine (*P. longaeva*), Engelmann spruce (*Picea englemannii*) and white fir (*Abies concolor*). Alpine tundra covers the uppermost reaches of the Great Basin's highest mountains (Billings, 1951). As Mack and Thompson (1982) observed, the structure of the arid steppe plant communities of intermountain western North America, marked by (among other things) caespitose grasses and a widespread cryptogamic crust, is not consistent with the past presence of substantial herds of large mammals of any sort. Indeed, the Great Basin is not the kind of area that one associates with bison (*Bison bison*) at all.

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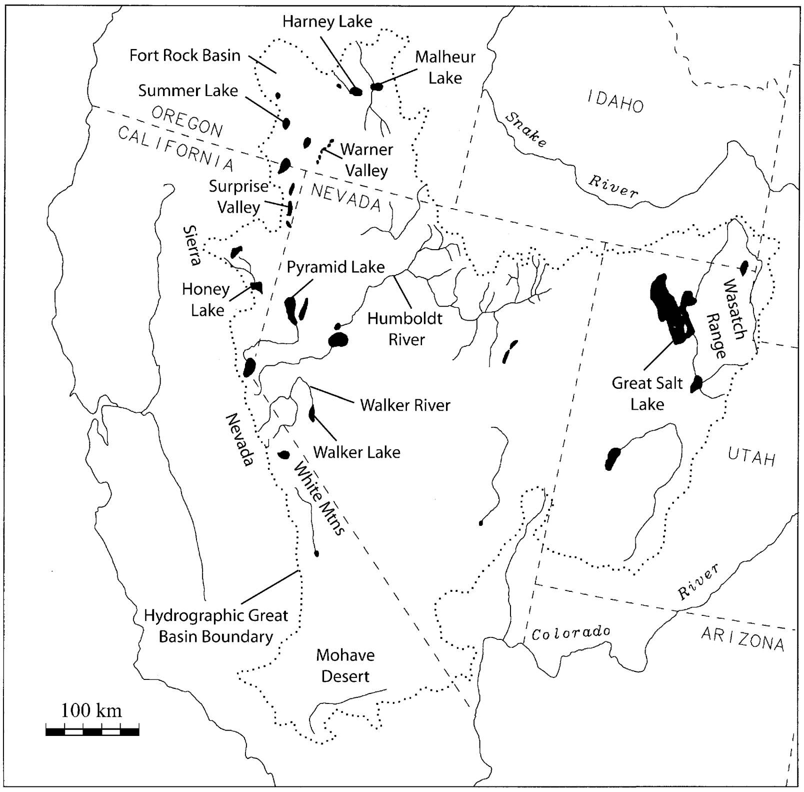

Figure 1 The Great Basin (dotted line), with selected locations of geographic features discussed in the text

The historic distribution of bison in the Great Basin

Even though this is the case, there were bison in at least parts of the Great Basin during the Holocene. Unfortunately, maps showing the historic distribution of bison in and near this region have in common the fact that they all differ from one another. Hall (1981) placed them in northeastern California, the eastern half of Oregon and all but western- and southernmost Utah, but not in Nevada. Reynolds *et al.* (2003) included eastern Oregon and northeastern California and much of Utah but placed them in far northern Nevada as well. McDonald (1981) placed the western edge of historic bison distribution at the eastern edge of the Cascade Range in Oregon and throughout northeastern California. He is the only author to have suggested that bison may have been found historically throughout much of the Great Basin.

There are good reasons for these very different renderings of the historic distribution of bison in the intermountain west. With the exception of northern Utah, for which evidence abounds (Lupo, 1996), there is no direct observational evidence that bison were in the Great Basin historically. As a result, the most cautious approach to mapping their distribution has demanded that all parts of the Great Basin west of the Idaho–Oregon and Utah–Nevada border be excluded. This is essentially what Reynolds *et al.* (1982) did.

On the other hand, Native American oral accounts place bison in northeastern California (Merriam, 1926; Kelly, 1932; Riddell, 1952, 1960), south-central and eastern Oregon (Bailey, 1936; Van Vuren and Bray, 1985) and northeastern Nevada (Steward, 1938). The eastern Oregon and northeastern Nevada accounts are matched by discoveries of surficial bison remains (Bailey, 1936; Van Vuren and Bray, 1985; Van Vuren and Dietz, 1993; Verts and Carraway, 1998) and the same may be true for northeastern California (Riddell, 1952). These records can be taken to indicate that bison were found across the northern Great Basin. This is essentially what Hall (1981) suggested, although he excluded northern Nevada.

Of course, there is no way to assess the time depth of any oral histories in the absence of corroborating records, and surficial skeletal remains can be deeply prehistoric. Perhaps this is why Hall (1981) did not include central Nevada within the historic range of bison, even though he had earlier reported the discovery of a *B. bison* skull in the Simpson Park Range, central Nevada (Hall, 1961).

Prehistoric Holocene bison in the Great Basin

As a result, and barring the discovery of additional early historic written accounts, it is to the archaeological and palaeontological records that we must turn if the nature of the Holocene distribution of bison in the Great Basin is to be understood, much as has been done for other parts of western North America (eg, Langemann, 2004; Cannon and Cannon, 2004; Mead and Johnson, 2004). Fortunately, archaeologists have been fully aware of the importance of this issue and valuable reviews have recently appeared concerning the Holocene bison of Oregon (Stutte, 2004) and the Snake River Plain of southern Idaho (Plew and Sundell, 2000; see also Henrickson, 2004) and the late-Holocene bison of northeastern Utah (Lupo and Schmitt, 1997). Here I provide a synthesis of the Holocene history of bison for the Great Basin as a whole.

In doing this, I have not distinguished between modern *Bison bison* and its immediate late-Pleistocene ancestor *Bison antiquus*. Isolated and fragmentary postcranial bison specimens can rarely be identified to the species level (Hurlbert and Webb, 2001), but it is just such specimens that most Great Basin sites have provided. Chronology provides no secure guide since *Bison antiquus* is known from contexts as young as *c.* 4300 ^{14}C yr BP (McDonald and Lammers, 2002). However, all securely identified late-Holocene Great Basin bison specimens are of *B. bison* (eg, Cannon, 2004; Johnson *et al.*, 2005).

As background, I note that there are late-Pleistocene records for bison from throughout the Great Basin (FAUNMAP Working Group, 1994), including the Mojave Desert section of the southwestern Great Basin (Davis, 1978; Jefferson, 2003). A list of all prehistoric Holocene occurrences of bison in the Great Basin of which I am aware and for which basic data are available is provided in Table 1. To compile this list, I began with published syntheses of the Great Basin archaeological and paleontological mammal records, including FAUNMAP Working Group (1994), Jefferson *et al.* (1994, 2002, 2004), Gillette and Miller (1999), Lupo and Schmitt (1997), Miller (2002), and Stutte (2004). I then augmented the results of this compilation with an intensive search of the relevant literature and consultations with colleagues.

Table 1 also includes all dates associated with the listed sites; all sites with radiocarbon or other secure dates are plotted in Figure 2. The sites within the large ellipse are too numerous to be labelled separately, but dates for these sites are indicated in Table 1; unless otherwise indicated, all fall within the timespan of the Fremont archaeological tradition, which dates to between about 1600 and 600 ^{14}C yr BP (Madsen and Simms, 1998; Massimino and Metcalfe, 1999). The four smaller ellipses

Table 1 Prehistoric bison in the Great Basin

Site[a]	Analytical unit	Age[b]	NISP or MNI[c]	Date[d]	Reference
26Eu1320, Little Boulder Basin, NV	Assemblage	LH	1	170 BP	1
42Bo73, Great Salt Lake Basin, UT	Assemblage	LH	11	1150–1090 yr BP	2
42Bo1072, Great Salt Lake Basin, UT	Assemblage	LH	ND		3
42Sl197, Great Salt Lake Basin, UT	Assemblage	LH	40	1380–1130 yr BP	2
42Sl285, Great Salt Lake Basin, UT	Assemblage	LH	ND	F	4
42Wb42, Great Salt Lake Basin, UT	Assemblage	LH	4	F and < 600 yr BP	5
42Wb185, Great Salt Lake Basin, UT	Assemblage	LH	5	1430–560 yr BP	2
42Wb304, Great Salt Lake Basin, UT	Assemblage	LH	ND	1000 yr BP	2
42Wb317, Great Salt Lake Basin, UT	Assemblage	LH	6	1015–540 yr BP	2
42Wb331, Great Salt Lake Basin, UT	Assemblage	LH	2	< 600 yr BP	5
Baker Village, Snake Valley, NV	Assemblage	LH	137	980–680 yr BP	6
Bear River 1, Great Salt Lake Basin, UT	Assemblage	LH	1798	1065 yr BP	7
Bear River 2, Great Salt Lake Basin, UT	Assemblage	LH	1220	995 yr BP	8
Bear River 3, Great Salt Lake Basin, UT	Assemblage	LH	632	1450 yr BP	9
Beatty Springs, Goose Creek Mountains, UT	Assemblage	LH	2 (MNI)	2350 yr BP	10
Bonneville Estates, Lead Mine Hills, NV	Assemblage	MH	ND		11
Bonneville Estates, Lead Mine Hills, NV	Assemblage	LH	ND		11
Bronco Charlie Cave, Ruby Mountains, NV	Surface	NP	1		12
Camels Back Cave, Camels Back Ridge, UT	Stratum XVIIc	LH	3	790 yr BP	13
Camels Back Cave, Camels Back Ridge, UT	Stratum XIV	LH	1	3630–3160 yr BP	13
Camels Back Cave, Camels Back Ridge, UT	Stratum IV	MH	1	7350 yr BP	13
Cathedral Gorge, NV	Assemblage	LH	208	810–450 yr BP	14
Catlow Cave, Catlow Valley, OR	Stratum I	NP	24		15
Catlow Cave, Catlow Valley, OR	Stratum II	NP	4		15
Catlow Cave, Catlow Valley, OR	Stratum III	NP	1		15
Catlow Cave, Catlow Valley, OR	Direct Dates	LH	2	440–405 yr BP	16
Connley Cave 3, Fort Rock Basin, OR	Stratum 1	LH	1	3080 yr BP	17
Connley Cave 4, Fort Rock Basin, OR	Stratum 3	NP	8		17
Connley Cave 4, Fort Rock Basin, OR	Stratum 4	NP	19		17
Connley Cave 5, Fort Rock Basin, OR	Stratum 3	NP	12		17
Danger Cave, Silver Island Range, UT	Stratum DV	LH	8	3950–0 yr BP	18
Danger Cave, Silver Island Range, UT	Stratum DIII	MH	1		18
Danger Cave, Silver Island Range, UT	Stratum DII	EH	2	10 080–7920 yr BP	18
Dirty Shame Rockshelter, Owyhee Plateau, OR	Zone 4	MH	4	6845 yr BP	19
Dirty Shame Rockshelter, Owyhee Plateau, OR	Zone 5	NP	6	7925–7850 yr BP	19
Dry Creek Ranch, Simpson Park Mountains, NV	Assemblage	LH	1 (SK)		20
Ephraim, Sanpete Valley, UT	Assemblage	LH	ND	F	21
Five Finger Ridge, Clear Creek Canyon, UT	Assemblage	LH	39	840–650 yr BP	22
Fort Rock Cave, Fort Rock Basin OR	Stratum 1	NP	5		23
Garrison, Snake Valley, UT	Assemblage	LH	ND	F	24
Gatecliff Shelter, Toquima Range, NV	Stratum 1, Horizon 2	LH	1	650 yr BP	25
Gatecliff Shelter, Toquima Range, NV	Strata 3-5, Horizon 5	LH	1	3200–1250 yr BP	25
Gatecliff Shelter, Toquima Range, NV	Strata 3-5, Horizon 6	LH	1	3200–1250 yr BP	25
Gilbert Peak, Uinta Mountains, UT	Assemblage	LH	1 (SK)	150 yr BP	26
Goshen Island South, Utah Lake, UT	Assemblage	LH	8	< 600 yr BP	27
Hanging Rock Shelter, Hanging Rock Canyon, NV	Organic-Yellow	NP	2		28
Harney Dune, Harney Basin, OR	Direct Date	LH	1 (SK)	250 yr BP	29
Helmet Crawl Cave, American Fork Canyon, UT	Assemblage	NP	ND		30
Heron Springs, Utah Lake, UT	Assemblage	LH	13	650–440 yr BP	31
Hidden Cave, Eetza Mountain, NV	No Provenience	NP	1		32
Hinckley Mounds, Utah Lake Basin, UT	Assemblage	LH	ND	1265–920 yr BP	33
Hogup Cave, Hogup Mountain, UT	Stratum 16	LH	2 (MNI)	500–250 yr BP	34
Hogup Cave, Hogup Mountain, UT	Stratum 14	LH	2 (MNI)	1210–620 yr BP	34
Hogup Cave, Hogup Mountain, UT	Stratum 13	LH	1 (MNI)	F	34

Table 1 (*continued*)

Site[a]	Analytical unit	Age[b]	NISP or MNI[c]	Date[d]	Reference
Hogup Cave, Hogup Mountain, UT	Stratum 12	NP	4 (MNI)		34
Hogup Cave, Hogup Mountain, UT	Stratum 10	NP	1 (MNI)		34
Hogup Cave, Hogup Mountain, UT	Stratum 9	NP	2 (MNI)		34
Hogup Cave, Hogup Mountain, UT	Stratum 8	NP	3 (MNI)		34
Hogup Cave, Hogup Mountain, UT	Stratum 7	MH	2 (MNI)	6190 yr BP	34
Hogup Cave, Hogup Mountain, UT	Stratum 6	MH	1 (MNI)	6400–5960 yr BP	34
Hogup Cave, Hogup Mountain, UT	Stratum 5	MH	2 (MNI)	7250–5795 yr BP	34
Hogup Cave, Hogup Mountain, UT	Stratum 4	EH	1 (MNI)	7815 yr BP	34
James Creek Shelter, Marys Mountain, NV	F2	LH	2	750 yr BP	35
James Creek Shelter, Marys Mountain, NV	Horizon III	LH	15	1250–750 yr BP	35
James Creek Shelter, Marys Mountain, NV	Horizon II-KX	LH	5	MIXED:1240–240 yr BP	35
Juke Box Cave, Silver Island Range, UT	Assemblage	NP	ND		36
Juniper Lake, Alvord Desert, OR	Direct Date	LH	4	370–150 yr BP	37
Kachina Cave, Smith Creek Canyon, NV	Stratum 4	LH	ND	1350 yr BP	38
King's Dog, Surprise Valley CA	KIV (Alkali Phase)	LH	2	1330 yr BP	39
King's Dog, Surprise Valley CA	KII (Bare Creek Phase)	LH	3	3010–2690 yr BP	39
King's Dog, Surprise Valley CA	KI (Menlo Phase)	MH	> 14	5640 yr BP	39
Knoll, Great Salt Lake Basin, UT	Assemblage	LH	54	640 yr BP	40
Levee, Great Salt Lake Basin, UT	Assemblage	LH	624	1250–710 yr BP	40
Lost Dune, Blitzen Valley, OR	Assemblage	LH	1 (SK)[e]	450–260 yr BP	41
Malheur Lake, OR	Direct Dates	LH	30 (SK)[f]	400–250 yr BP	37
Marysvale, Sevier River Valley, UT	Assemblage	LH	ND	F	21
Median Village, Parowan Valley, UT	Assemblage	LH	2	1050–990 yr BP	42
Mosquito Willie, western Bonneville Desert, UT	Stratum 3, Test Unit 6	LH	1	> 2280 yr BP	43
Nawthis Village, Fishlake Plateau, UT	Assemblage	LH	9	1075–790 yr BP	44
Nightfire Island, Lower Klamath Lake, CA	Stratum 9	LH	12	4190–3200 yr BP	45
Nightfire Island, Lower Klamath Lake, CA	Stratum 8	LH	5	4190–4055 yr BP	45
Nightfire Island, Lower Klamath Lake, CA	Stratum 6	LH	9	4950–4350 yr BP	45
Nightfire Island, Lower Klamath Lake, CA	Stratum 5	LH	2	4630–4075 yr BP	45
Nightfire Island, Lower Klamath Lake, CA	Stratum 4	NP	2	*c* 4950 yr BP	45
O'Malley Shelter, Clover Valley, NV	Unit 1	MH	2	7100–6520 yr BP	46
Oranjeboom Cave, Goshute Mountains, NV	Assemblage	LH	6	1220–1060 yr BP	47
Orbit Inn, Great Salt Lake Basin, UT	Assemblage	LH	29	570–300 yr BP	2
Paisley Cave 2, Summer Lake Basin, OR	Direct Date	LH	1	845 yr BP	37
Parowan Canyon, UT	Assemblage	NP	1 (SK)		48
Peninsula, Warner Valley, OR	Structure 1	LH	1	625–240 yr BP	49
Pharo Village, Scipio Valley, UT	Assemblage	LH	18	760–690 yr BP	50
Porcupine Cave, Uinta Mountains, UT	Bridge Junction	NP	1		51
Promontory Cave, Salt Lake Basin, UT	Assemblage	LH	20	1310–840 yr BP	52
Pyramid Lake Fishway 1016, Pyramid Lake Basin, NV	Assemblage	LH	1	3015 yr BP	53
Roaring Springs Cave, Catlow Valley, OR	Assemblage	NP	1		54
Roaring Springs Cave, Catlow Valley, OR	Direct Dates	LH	2	480–410 yr BP	55
Rock Springs, Curlew Valley, ID	Bone Bed 1	LH	120	Historic	56
Rock Springs, Curlew Valley, ID	Bone Bed 2	LH	212	290 yr BP	56
Rock Springs, Curlew Valley, ID	Bone Bed 3	LH	224	370 yr BP	56
Rock Springs, Curlew Valley, ID	Bone Bed 4	LH	112	730 yr BP	56
Rock Springs, Curlew Valley, ID	Bone Bed 5	LH	213		56
Rock Springs, Curlew Valley, ID	Bone Bed 6	LH	52		56
Rock Springs, Curlew Valley, ID	Bone Bed 7	LH	12	840 yr BP	56
Sandy Beach, Utah Lake, UT	Assemblage	LH	1	510–450 yr BP	31
Skull Creek Dunes, Catlow Valley, OR	Direct Date	LH	6	450 yr BP	55
Smoking Pipe, Utah Lake Basin, UT	Midden	LH	1831	890–350 yr BP	31
Snake Rock Village, Castle Valley, UT	Assemblage	LH	1	F	57
Spotten Cave, Goshen Valley, UT	Zone 3	LH	1 (MNI)	1310–730 yr BP	58
Spotten Cave, Goshen Valley, UT	Zone 5	LH	1 (MNI)		58
Susie Creek, Adobe Range, NV	Assemblage	LH	1 (SK)	950 yr BP	59
Swallow Shelter, Goose Creek Mountain, UT	Stratum 10	LH	3 (MNI)	to 600 yr BP	10
Swallow Shelter, Goose Creek Mountain, UT	Stratum 9	LH	1 (MNI)	1120 yr BP	10
Swallow Shelter, Goose Creek Mountain, UT	Stratum 8	LH	1 (MNI)		10
Swallow Shelter, Goose Creek Mountain, UT	Stratum 6	LH	1 (MNI)		10
Swallow Shelter, Goose Creek Mountain, UT	Stratum 5	LH	1 (MNI)	2630 yr BP	10
Swallow Shelter, Goose Creek Mountain, UT	Stratum 4	LH	2 (MNI)	2850 yr BP	10
Swallow Shelter, Goose Creek Mountain, UT	Stratum 3	LH	1 (MNI)	3500 yr BP	10
Tooele, Great Salt Lake Basin, UT	Assemblage	LH	ND	F	21
Tosawihi Quarry (26Ek3092), Antelope Creek, NV	Assemblage	NP	1		60
Tosawihi Quarry (26Ek3200), Antelope Creek, NV	Assemblage	NP	1		60
Trego Hot Springs (26Pe118), Black Rock Desert, NV	Assemblage	LH	217	3040–1120 yr BP	61
Wallman Bison, Black Rock Desert, NV	Assemblage	NP	*c.* 20		62

Table 1 (*continued*)

Site[a]	Analytical unit	Age[b]	NISP or MNI[c]	Date[d]	Reference
Warren, Great Salt Lake Basin, UT	Assemblage	LH	75	1180 yr BP	2
Wells Dump, Humboldt River Basin, NV	Assemblage	LH	ND	750 yr BP	63
Wells NE, Humboldt River Basin, NV	Assemblage	NP	1 (SK)		59
Willard Mounds, Great Salt Lake Basin, UT	Assemblage	LH	94	1250–690 yr BP	2
Woodruff Bison Kill, Wyoming Basin, UT	Assemblage	LH	1150	1335 yr BP	64

[a] Cave and rockshelter sites are in italics; all others are open sites.
[b] Sites, or strata within sites, are placed within chronological subdivisions of the Holocene (EH, early Holocene, 10 000 yr–7500 ^{14}C yr BP; MH, middle Holocene, 7500–4500 ^{14}C yr BP; LH, late Holocene, 4500 ^{14}C yr BP–latest prehistoric; NP, cannot be placed in the tripartite sequence).
[c] NISP, Number of Identified Specimens; MNI, Minimum Number of Individuals; MNI values are labelled as such and are given only when NISP values are unavailable (ND, no data; SK, skull).
[d] Uncalibrated radiocarbon dates; sites indicated as ‘F’ in this column lack radiocarbon dates but are associated with the Fremont archaeological tradition, dated to *c*. 1600–600 yr BP.
[e] Additional uncounted specimens present.
[f] 30 skulls have been reported from Malheur Lake, of which three have been dated (Stutte, 2004).
References: (1) Schroedl, 1995; (2) Lupo and Schmitt, 1997; Coltrain and Stafford, 1999; Simms, 1999; (3) Lambert and Simms, 2003; (4) Coltrain and Leavitt, 2002; (5) Fawcett and Simms, 1993; Lupo, 1993; (6) Wilde, 1992; Hockett, 1998; (7) Aikens, 1966; Lupo and Schmitt, 1997; (8) Madsen and Rowe, 1988; Lupo and Schmitt, 1997; (9) Shields and Dalley, 1978; Lupo and Schmitt, 1997; (10) Dalley, 1976; (11) B.S. Hockett, personal communication, 2005; Rhode *et al.*, 2005; (12) Spiess, 1974; (13) Schmitt and Lupo, 2005; (14) Johnson *et al.*, 2005; (15) Cressman, 1942; Wilde, 1985; (16) Wilde, 1985; Stutte, 2004; (17) Bedwell, 1973; Grayson, 1979; Jenkins *et al.*, 2002; D.L. Jenkins, personal communication, 2005; (18) Jennings, 1957; Grayson, 1988; Rhode and Madsen, 1998; Rhode *et al.,* 2006; (19) Aikens *et al.*, 1977; Grayson, 1977; (20) Hall, 1961; Jefferson *et al.*, 2004; (21) Gillin, 1941; (22) Talbot *et al.*, 2000; (23) Grayson, 1979; (24) Taylor, 1954; (25) Grayson, 1983; Thomas, 1983; (26) Cannon, 2004; (27) J.C. Janetski, personal communication, 2005; (28) Grayson and Parmalee, 1988; (29) Raymond, 1994; Stutte, 2004; (30) Miller, 2002; (31) Billat, 1985; Janetski, 1990; Lupo and Schmitt, 1997; (32) Grayson, 1985; (33) Green, 1961; Lupo and Schmitt, 1997; (34) Aikens, 1970; Durrant, 1970; (35) Budy and Katzer, 1990; Grayson, 1990; (36) Jennings, 1957; (37) Stutte, 2004; (38) Miller, 1979; Mead *et al.,* 1982; Tuohy, 1979; (39) O’Connell, 1975; James, 1983; O’Connell and Inoway, 1994; J.F. O’Connell, personal communication, 2005; (40) Fry and Dalley, 1979; Lupo and Schmitt, 1997; (41) Lyons and Mehringer, 1996; Lyons and Cummings, 2002; Stutte, 2004; (42) Marwitt, 1970; (43) Janetski, 2004; (44) Sharp, 1992; (45) Sampson, 1985; (46) Fowler *et al.*, 1973; (47) Buck *et al.*, 2002; (48) Presnall, 1938; (49) Eiselt, 1998; (50) Marwitt, 1968; Lupo and Schmitt, 1997; (51) Haman, 1963; Heaton, 1988; (52) Aikens, 1966; Marwitt, 1970; Lupo and Schmitt, 1997; (53) Clark and Anderson, 1979; (54) Cressman, 1942; Wilde, 1985; (55) Wilde 1985; Stutte, 2004; (56) Arkush, 2002; (57) Aikens, 1967; (58) Cook, 1980; Lupo and Schmitt, 1997; (59) Van Vuren and Dietz, 1993; (60) Elston and Raven, 1992; Schmitt, 1992; (61) Dansie, 1980; Seck, 1980; (62) Dansie *et al.*, 1988; (63) Hockett and Morgenstein, 2003; (64) Shields, 1978; Lupo and Schmitt, 1997.

in Figure 2 indicate areas in which oral tradition and surficial discoveries of bison remains have been taken by some to indicate the historic presence of these animals (there is an ellipse in south-central Oregon that is nearly hidden by dated sites; the known historic distribution of bison in Utah is not shown).

The general pattern

As Figure 2 shows, bison were once widespread across the eastern and northern parts of the Great Basin during the Holocene. However, this distribution is primarily a phenomenon of the very late Holocene (Figures 3–5). Of the 103 records that can be placed within the tripartite subdivision of the Holocene (Table 1), 90 are late Holocene in age. Of these 90, 80 are sufficiently well dated that their chronological placement within the late Holocene can be determined. Of those 80, 67 (84%) post-date *c.* 1600 ^{14}C yr BP (the record for James Creek Shelter Horizon II-KX has not been counted because it is from a stratigraphically mixed assemblage that may include material from Horizon III, which has been counted). The record thus suggests that bison were widespread in much of the northern and eastern Great Basin during the very late Holocene but were far less common before then. It also suggests that bison were not to be found in the southwestern quadrant of the Great Basin any time during the past 10 000 years. In this, the Holocene record differs from that of the late Pleistocene, since, as I have noted, late-Pleistocene bison are known from the Mojave Desert.

Unfortunately, the early and middle Holocene records for Great Basin bison are not likely to represent samples that are comparable with those available for the late Holocene. The Great Basin has provided a superb Holocene record of small-mammal history, based on data from a wide variety of archaeological and paleontological sites (eg, Grayson, 2000; Hockett, 2000; Schmitt *et al.*, 2002). The core small-mammal sequences, however, are from caves, and diverse mechanisms introduce vertebrate remains into such settings. The situation is quite different for bison. Although large bovids are known to enter caves on their own (Lyman, 1988), the most obvious mechanism to introduce their remains into these sites in the Great Basin is people. It follows that the cave record for bison can be expected to correlate positively with both bison and human population densities on the prehistoric Great Basin landscape. It has long been known that, compared with the late Holocene, there were relatively few people in the Great Basin during the middle Holocene (see the review in Grayson, 1993) and recent work strongly suggests that human population densities were also low during the early Holocene (Jones *et al.*, 2003). If the most obvious mechanism available to introduce bison remains into Great Basin caves was uncommon prior to the late Holocene, then the cave record for the early and middle Holocene is not likely to provide trustworthy information on the distribution of these animals.

In addition, the large size of bison presents a transport challenge for hunting and gathering societies. As a result, and because caves are uncommon on the landscape, the bony

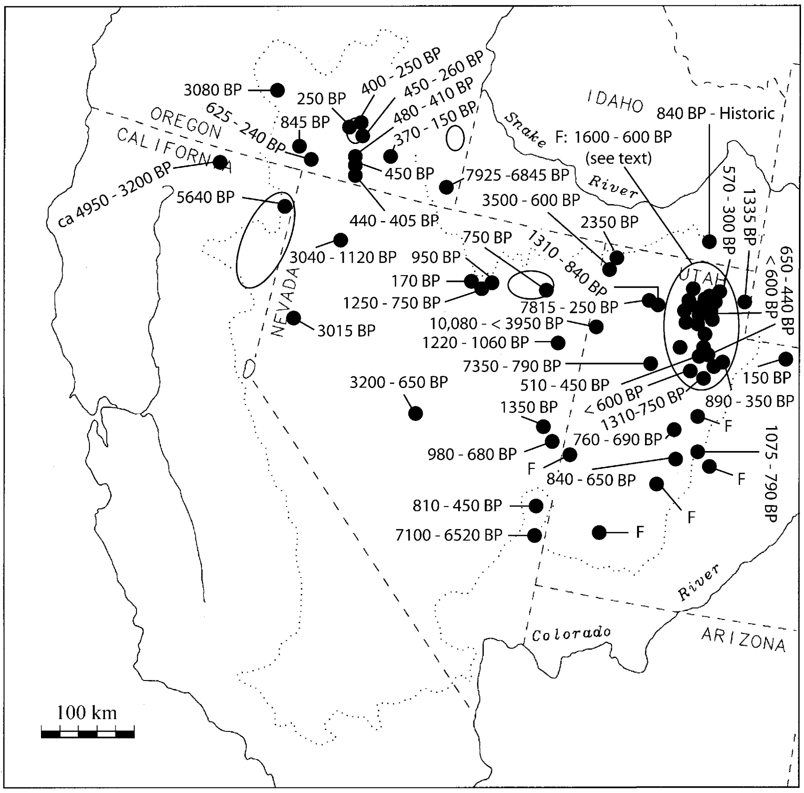

Figure 2 The distribution of dated prehistoric Great Basin archaeological and paleontological sites that have provided bison remains (all ages are in radiocarbon years). The ellipses in California, Oregon and Nevada mark areas in which bison have been thought to have occurred during latest prehistoric or early historic times based on oral tradition and/or the discovery of surficial bison remains. The historic distribution of bison in Utah is not shown

residues of bison hunting can be expected to be found most frequently in open sites. Unfortunately, buried open archaeological sites are notoriously rare for the early-Holocene Great Basin (Beck and Jones, 1997) and not much more common for the middle Holocene (Grayson, 1993); they become frequent only after that time. This is probably a prime reasons why 62 of the 64 records from open sites that can be placed within the tripartite subdivision of the Holocene are late Holocene in age

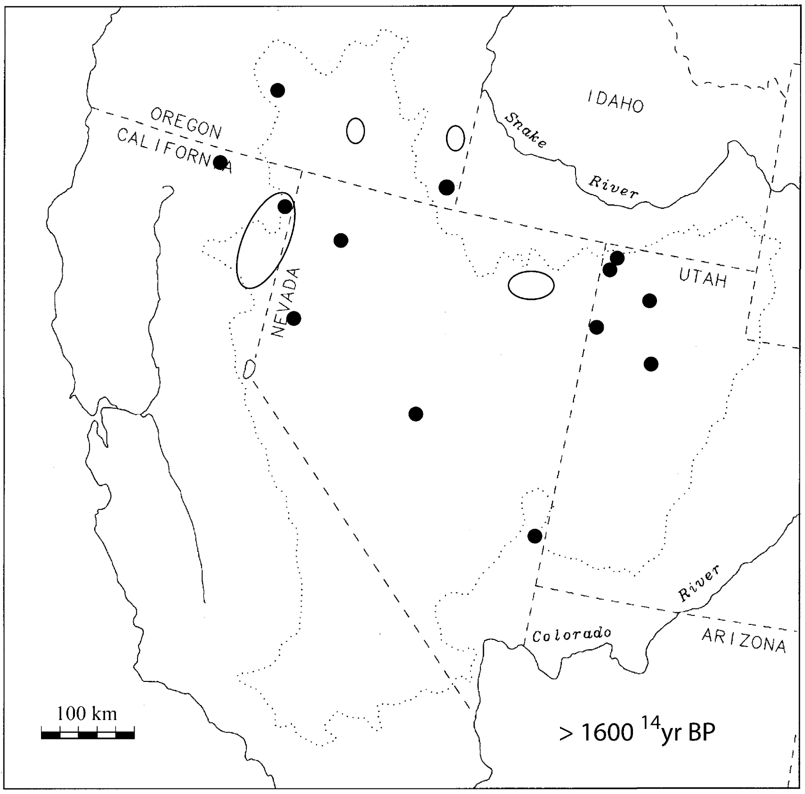

Figure 3 The distribution of Great Basin Holocene sites with bison older than *c.* 1600 ^{14}C yr BP

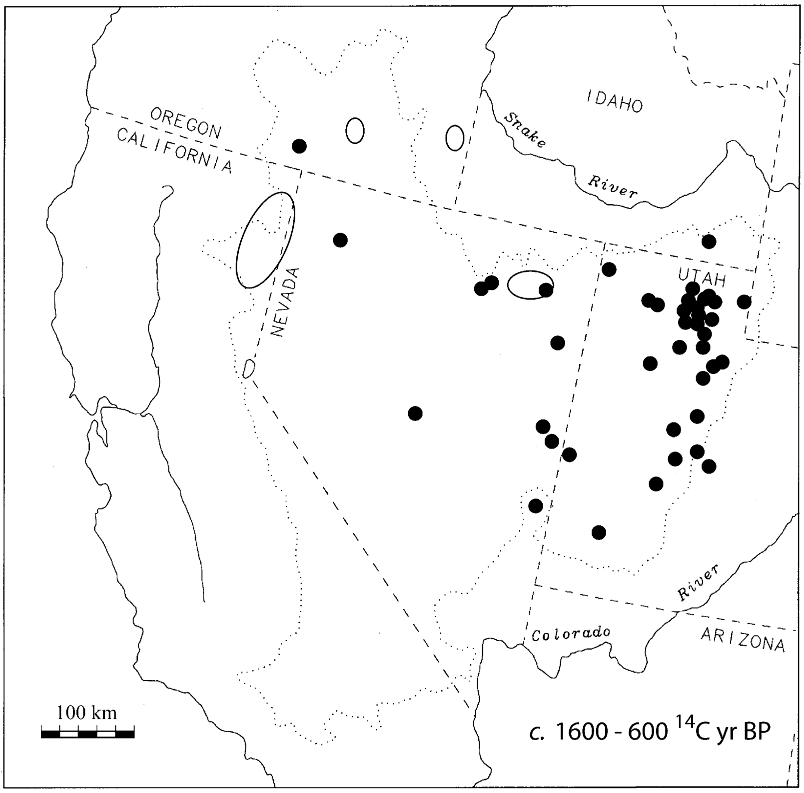

Figure 4 The distribution of Great Basin Holocene sites with bison that date to between *c*. 1600 and 600 ^{14}C yr BP

(Table 1). Of these 62, 57 are demonstrably archaeological (the exceptions are Cathedral Gorge, Dry Creek Ranch, Gilbert Peak, Malheur Lake, Susie Creek and perhaps 36Bo1072). As a result, it is no surprise that open sites are significantly under-represented in the early- and middle-Holocene Great Basin bison sample ($\chi^2 = 13.82$, $p < 0.001$, excluding James Creek II-KX).

These issues suggest that our current record of Great Basin bison history is not likely to be particularly accurate for the early and middle Holocene, but that the record for the past

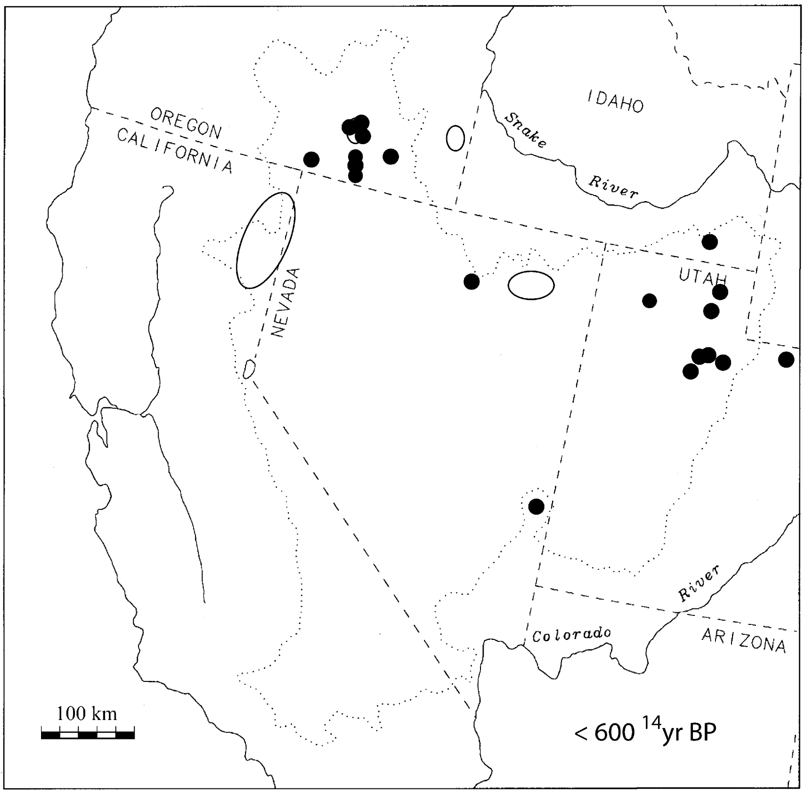

Figure 5 The distribution of Great Basin Holocene sites with bison that date to less than 600 ^{14}C yr BP

4500 years or so probably does provide a representative sample of that history.

The western, northern, and central Great Basin

Of the four areas within the Great Basin for which the historic presence of bison has been asserted solely on the basis of oral histories and the presence of surficial bison remains, only south-central Oregon can convincingly be shown to have supported these animals during very recent times. Here, recent work by Stutte (2004) has shown that numerous sites in and near the Malheur and Harney basins contain bison that were deposited within the last 500 radiocarbon years or so (Table 1, Figure 1). This work confirms the suggestion made by Bailey (1936) and others that bison were to be found in this part of the Great Basin in the very recent past.

The most recent date for bison in northeastern California comes from the KIV component at the King's Dog site (Surprise Valley, California) and falls at 1330 ^{14}C yr BP (O'Connell and Inoway, 1994; see also O'Connell and Ericson, 1974; O'Connell, 1975). This component provided two specimens of bison, but it also contained large numbers of projectile points that are stylistically characteristic of the middle Holocene in this area and that are common in the deepest section of the site. This raises the strong possibility that the late-Holocene bison at King's Dog, including both the KIV material and the three specimens from late-Holocene component KII, may have been displaced upwards from the middle-Holocene unit (KI), which contains substantial numbers of bison specimens (J.F. O'Connell, personal communication, 2005). Only direct dating of the specimens involved could solve this problem, but King's Dog does not provide secure evidence of late-Holocene bison in northeastern California. For this reason, only the middle-Holocene date from King's Dog has been depicted on Figure 2. Just as important, recent intensive work on several dozen archaeological sites in this area, including locations specifically mentioned by Merriam (1926) and Riddell (1952) as supporting bison historically – for instance, Madeline Plains and Honey Lake Valley – did not provide a single specimen of this animal (K.L. Carpenter, 2002, personal communication, 2005).

To the immediate northeast in far south-central Oregon, bison has been reported from Paisley Cave 2 (Summer Lake basin), where it has been directly dated to 845 ^{14}C yr BP (Stutte, 2004), and from the Peninsula site (Warner Valley: Moore, 1995; Eiselt, 1998). The latter site provided a single bison specimen, a tooth, from a house structure with dates ranging from 625 to 240 ^{14}C yr BP. Three of these dates are on construction logs and thus may be older than the structure itself. As a result, Eiselt (1998) preferred the 240 ^{14}C yr BP date, obtained from basketry found within the structure. This is the only late-prehistoric specimen of bison reported from this area. Since the Warner Valley has also been the focus of substantial archaeological work, it seems unlikely that the near lack of records for bison in this area reflects inadequate sampling efforts. While there is no reason to question the accuracy of the oral histories suggesting the presence of bison in northeastern California, the archaeological record as yet provides little support for the suggestion that those histories refer to very recent times.

In northwestern Nevada, only the Trego Hot Springs site (southeastern edge, Black Rock Desert), has provided late-Holocene bison remains. While these specimens are plentiful – 217, perhaps belonging to a single individual – their stratigraphic position is unclear. Information provided by Dansie (1980) and Seck (1980), who analysed material excavated by others, suggests the bison specimens came from stratigraphic unit 2, associated with dates that fall between 3040 and 1120 ^{14}C yr BP. These are the dates provided in Figure 2, although, as with King's Dog, direct dates on this material would be helpful. It does not appear likely, however, that they are latest Holocene in age.

Much the same can be said for northeastern Nevada. Although a number of sites in this area have provided prehistoric bison remains, only one of these, 26Eu1320 (Little Boulder Basin, Humboldt River drainage), suggests that bison may have been present here in late prehistoric or early historic times. This site provided a single specimen identified as cf. *Bison bison*, found within a rock-lined fire pit that also provided a date of 170 ^{14}C yr BP (Schroedl, 1995). Alongside it were found three specimens identified as *Bos*/*Bison*; four other large bovid specimens were found near the same feature. While the cf. *Bison bison* specimen bore cut marks, none of the large bovid bones within the fire pit had been burned, suggesting they were introduced after the fire had been extinguished and that the radiocarbon date, on charcoal, may not apply to those specimens. Given this, given that the site had been subjected to significant vertical mixing and given the tentative nature of the *Bison* identification, 26Eu1230 does not provide compelling evidence for late prehistoric or historic bison in this part of Nevada. The next-most recent bison remains from northeastern Nevada date to 750 ^{14}C yr BP (Wells Dump, Humboldt River basin).

The situation for eastern Oregon (which lies outside the Great Basin) is somewhat different. Here, no late-Holocene records for bison have been reported, but this is an area that has seen relatively little archaeological and paleontological work and the absence of documented late-prehistoric bison from this region may simply reflect this fact. Bison remains dating to between 2000 and 150 ^{14}C yr BP are known from the Jump Creek site in the western Snake River Plain, not far to the northeast of the possible eastern-Oregon historic records (Plew and Sundell, 2000).

In short, recent work by Stutte (2004) leaves no question that there were bison in south-central Oregon during early-historic times, just as Bailey (1936) argued. Although bison may well have been in northeastern California, far eastern Oregon and northeastern Nevada at the same time, it cannot currently be shown that this was the case.

The eastern Great Basin

If one were to draw a line encircling those parts of far-eastern Nevada and western Utah that have not provided late-Holocene bison remains, the results would provide a good approximation of the basin of Pleistocene Lake Bonneville.

Most bison-bearing sites in this area are associated with the Fremont archeological tradition, a name applied to people who made their living through a combination of farming, hunting and gathering in the eastern Great Basin and adjacent Colorado Plateau between about 1600 and 600 ^{14}C yr BP (Madsen and Simms, 1998; Massimino and Metcalfe, 1999). This same interval saw the Great Salt Lake reach what appears to have been its latest prehistoric highstand (at *c.* 1000 ^{14}C yr BP; see Broughton, 2000; Broughton *et al.*, 2000). A number of authors have called on a wide variety of palaeobotanical data to document that this was also a period when the Fremont area saw increased summer temperatures, summer moisture and grass abundance (Hemphill and Wigand, 1995; Wigand, 1997; Rhode, 2000; Wigand and Rhode, 2002). These authors, as well as Lupo and Schmitt (1997), associated these changes with the abundance of bison so evident in Fremont-aged sites (Figure 4). They also associated warm and wet winters with the fact that Fremont peoples were maize horticulturalists and that maize requires both summer moisture and a lengthy growing season (Salzer, 2000; see also Talbot *et al.*, 2000). While maize is known from this area as early as *c.* 2100 yr BP (Wilde and Newman, 1989), maize horticulture did not become common here until Fremont times and is not known from this area after the Fremont tradition disappears. In accord with all of this, Lupo and Schmitt (1997) observed that bison seem to have become less abundant after about 600 ^{14}C yr BP in northeastern Utah (Figure 5). This is roughly the time when, as Wigand (1997), Madsen and Simms (1998), Rhode (2000) and Wigand and Rhode (2002) have noted, this area also saw declines in summer temperature, summer precipitation and grass abundance.

Although Fremont hunting must have taken a toll on local bison populations, as it did on other artiodactyls in the Great Basin (Janetksi, 1997; Grayson, 2001; see also Ugan, 2005), post-Fremont human population densities seem to have been lower than those during Fremont times (Janetski, 1994). Since bison numbers also declined after the Fremont demise, climatic change would seem to provide a better explanation for this decline than would the impact of human hunters.

The association of increased summer temperature with increased precipitation in the eastern Great Basin is explained by the fact that the Great Basin derives at least two-thirds of its summer rainfall from monsoonal storms that enter the region from the south. These storms have their greatest impact on the southern and eastern Great Basin (Houghton, 1969). Increased summer temperatures would strengthen the incursions of these storms, and this appears to be what happened between about 1600 and at least 800 ^{14}C yr BP ago in the Fremont area.

The palaeoclimatic records from the Fremont area are matched by records to the south. Both Peterson (1994) and Benson *et al.* (2006) used the local history of pinyon pine (*Pinus edulis*) to document strengthened summer monsoons between about 1200 and 800 cal. yr BP in southwestern Colorado (their record begins at *c.* 1200 cal. yr BP). Using tree-ring data from west-central New Mexico and foraminifera abundances from a core in the northern Gulf of Mexico, Poore *et al.* (2005) argued for significant monsoonal strengthening in the southwest at 1400 and 900 cal. yr BP. These reconstructions coincide with the increase in bison abundance to the north during Fremont times.

Salzer (2000) has used dendroclimatological data to show that annual temperatures in the San Francisco Peaks area of northern Arizona were markedly depressed for much of the interval between 750 and 675 cal. yr BP. This result matches pollen-based evidence presented by Peterson (1994) for the onset of dry and cold conditions at about 750 cal. yr BP in the La Plata Mountains of southwestern Colorado. As Benson *et al.* (2006) discussed, the San Juan Basin saw major droughts at *c.* 800 and 670 cal. yr BP, both of which may have been associated with a weakened summer monsoon. They also observed that the 800 cal. yr BP drought coincides with a strong decline in maize consumption in the Fremont area (Coltrain and Leavitt, 2002), while the 650 cal. yr BP drought coincides with the end of Fremont and with archaeological site abandonment in the northern Southwest. Indeed, these droughts have been documented from a wide variety of locations within the Great Basin itself, with greatly reduced levels in Pyramid (Benson *et al.*, 2002; Mensing *et al.*, 2004), Walker (Yuan *et al.*, 2004) and Mono (Stine, 1994) lakes and in Walker River (Stine, 1994). Tree-ring data from the southern Sierra Nevada and from the White Mountains of eastern California document elevated temperatures and greatly decreased precipitation around 650 cal. yr BP (Graumlich, 1993; Hughes and Graumlich, 1996), while the period from 700 to 662 cal. yr BP saw severe drought in the Uintah Basin watershed of northeastern Utah (Gray *et al.*, 2004).

These climatic events – the weakening of monsoonal incursions after *c.* 750 cal. yr BP and severe drought at *c.* 800 and 650 cal. yr BP – appear to coincide closely with the decrease in bison abundance in the eastern Great Basin discussed above and to have caused the southern edge of bison distribution in the Great Basin to have moved significantly northwards (compare Figures 4 and 5). Unfortunately, it is not yet possible to build a chronology of bison abundances during Fremont times sufficiently precise to compare with the details of palaeoclimatic sequences from either the Great Basin or the Southwest. Nonetheless, current data strongly suggest that both the intensity of maize horticulture and bison abundances were driven by the history of monsoonal storm systems in the eastern Great Basin, just as others have suggested.

Summer monsoonal rainfall is relatively unimportant in the northern Great Basin of south-central Oregon. Although Wigand and Rhode (2002) provided evidence for increased summer moisture in the northern Great Basin beginning at about 1600 ^{14}C yr BP, this increase seems less pronounced than it is in the Bonneville Basin (Wigand, 1987). These differences may explain why there is so little evidence for bison in this area between 1600 and 500 ^{14}C yr BP, compared with the great abundance of such evidence in the eastern Great Basin. This is the case even though there has been a substantial amount of archaeological work in the Malheur and Harney basins in the heart of this region (eg, Raven and Elston, 1992; Elston and Dugas, 1993; Musil, 1995).

The appearance of bison in south-central Oregon after 500 ^{14}C yr BP may be a function of the increased winter moisture and cooler temperatures that marked this region during the 'Little Ice Age', which began about 350 ^{14}C yr BP (Wigand, 1987, 2004; Wigand and Rhode, 2002). No matter what the cause of this increase, however, it is not clear why Holocene-aged bison remains are nearly absent from the far northwestern corner of the Great Basin (Figure 2). In spite of intensive archaeological work here during the past two decades (Aikens and Jenkins, 1994; Jenkins *et al.*, 2004), only a single late-Holocene record for bison is available from this region (Connley Cave 3, 3080 ^{14}C yr BP; the records from Connley Caves strata 3 and 4 are either early Holocene or late Pleistocene). This is especially perplexing since there are no obvious biogeographic barriers to prevent the movement of bison between the Malheur and Harney basins, on the one hand, and the Fort Rock Basin on the other. There is also no reason to think that climatic change that impacted the Malheur and Harney basins would not have impacted the adjacent northwestern corner of the Great Basin as well.

Conclusions

Archaeological and palaeontological records document that bison were widespread in the eastern and northern parts of the Great Basin during the late Holocene, particularly after 1600 ^{14}C yr BP. It is unlikely to be coincidental that Plew and Sundell (2000) found exactly the same chronological pattern for the Snake River Plain of southern Idaho. Just as they have also observed for the Snake River Plain, the relatively small numbers of bison specimens that are generally provided by these sites suggests the existence of small herds of these animals, as opposed to the huge agglomerations that characterized the Great Plains during early historic times. Perhaps surprisingly, of the four areas within the Great Basin for which there is anecdotal evidence of the historic presence of bison, only one – south-central Oregon – has provided compelling empirical data in support of that evidence. For the other three – northeastern California, eastern Oregon and northeastern Nevada – there is currently no convincing archaeological or palaeontological indication that bison were present during latest prehistoric and early historic times.

The densest concentrations of Great Basin bison during the late Holocene were found in the eastern Great Basin, in the area immediately surrounding the basin of Pleistocene Lake Bonneville. Bison populations flourished here between about 1600 and 600 ^{14}C yr BP (Figures 3–5), a fluorescence that seems to have been tied to deeper incursions of monsoonal storms, the same storms that allowed Fremont peoples to practice maize horticulture. Once those incursions weakened, maize horticulture disappeared from this region, bison populations seem to have decreased, and the southern edge of bison distribution in the Great Basin moved northwards. To the northwest, in south-central Oregon, bison appear in the archaeological record after *c*. 500 ^{14}C yr BP, perhaps associated with increased winter moisture and cooler summer temperatures. If these reconstructions are correct, then bison abundances in the sagebrush-steppe vegetation of the Great Basin changed in concert with fluctuations in both winter and summer precipitation. Presumably, increased precipitation led to more substantial grass cover and thus improved bison habitat.

The Great Basin is not the only western North American desert to have supported bison prehistorically. As Mead and Johnson (2004) have observed, they were also found in Arizona during, and perhaps throughout, the Holocene; these authors provide a record from far-southwestern Arizona that dates to very late prehistoric or early historic times. This is the case even though Hall (1981) does not include Arizona within the historic range of this animal. A more complete understanding of the history of bison in the arid western USA awaits a synthesis of these southwestern records, as Mead and Johnson (2004) urge, as well as an increased emphasis on building improved chronologies for far-western North American bison in general.

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