Unusual Holocene alluvial record from Rio del Oso, Jemez Mountains, New Mexico: Paleoclimatic and archaeologic significance


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UNUSUAL HOLOCENE ALLUVIAL RECORD FROM RIO DEL OSO, JEMEZ MOUNTAINS, NEW MEXICO: PALEOCLIMATIC AND ARCHAEOLOGIC SIGNIFICANCE

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ABSTRACT — The lower Rio del Oso valley is characterized by a single Holocene terrace that is formed by 3 to 5 m of largely overbank fine quartz sand dated by 22 radiocarbon dates between 4610 and 640 14C yrs BP making this one of the best dated sequences in the region. The alluvium contains seven cumulic A horizon paleosols, 5 to 62 cm thick, a remarkable feature seldom seen in other alluvial records. The thickest paleosol “F” formed ca. 3000 to 2000 14C yrs BP and was a valley-wide floodplain soil while the other paleosols were only local in extent. The paleosols are dark brown to very dark grayish brown in contrast to the light to pale brown nonpaleosol alluvium. The paleosols are characterized by 0.3 to 0.5% organic carbon and 8 to 9% silt, the silt originating in part by atmospheric dust influx. The alluvial sedimentation rate is 0.075 cm per calendar year, r = 0.98. The Rio del Oso record of deposition and erosion correlates with other records on the Pajarito Plateau that in turn contrast sharply with regional sequences. Specifically, southwest-southern plains alluvial valleys were trenched 1000 14C yrs BP while the Oso and Pajarito-area valleys were not and alluviation continued to 600 14C yrs BP. Since regional downcutting was a response to a shift from moist to dry climate and the Oso and other Jemez area streams were evidently not significantly influenced by this episode of climate change, the Jemez Mountains may be providing a local mesic environment, resulting in local alluvial sequences that differ from those in the greater Southwest. Several in situ prehistoric features were observed at 2 to 4 m depth in the alluvium and are dated about cal BC 3500 to BC 800. After ca. 600 14C yrs BP, the Oso valley floodplain was incised and the broad floodplain was largely removed by erosion; the Holocene terrace is a remnant of that surface. Late prehistoric agriculture on the Oso valley floodplain, whether or not irrigated, would have been dramatically changed by incision and erosion of the floodplain.

INTRODUCTION

The Rio del Oso is a near-permanent stream fed by snow melt, rainfall, and numerous springs in the Jemez Mountains of north-central New Mexico. Its narrow watershed covers 108 km2 and begins on the north slope of Chicoma Mountain at 3524 m elevation, the highest peak in the volcanic Jemez Mountains. The Rio del Oso flows 26 km northeasterly through the Jemez, dropping to 1743 m elevation where it enters the Rio Chama at the community of Chili, southeastern Rio Arriba County, along U.S. Highway 84 (Fig. 1). Detailed weather records in Los Alamos County south of Rio del Oso indicate that annual rainfall ranges from about 280 to 890 mm from low to high elevations along the eastern slope of the Jemez Mountains (Reneau and McDonald, 1996).

The upper Rio del Oso drainage is developed in the Tschioma Formation dacite, a series of extrusive flows and domes of Pliocene volcanic rock at the northeastern margin of the Jemez Mountains (Smith et al., 1970). The lower Oso valley is cut into the weakly indurated Miocene Ojo Caliente Sandstone Member of the Tesuque Formation (Santa Fe Group) (Dethier and Manley, 1985). Lobato Mesa in the upper watershed and north-south trend ing dikes in the lower Oso valley are outcrops of black vesicular basalt of the Lobato Formation (Koning et al., 2005) and are the source for the basalt gravels in the Oso alluvium. Previous investigations of Rio del Oso alluvium are reported by Dethier and Demsey (1984) and Periman (2001, 2005).

HIGH PLEISTOCENE TERRACE

Superimposed on eroded Tertiary bedrock are thick deposits of Pleistocene gravels occurring at different elevations along the valley margins of the Rio Chama. The gravels represent former channel positions of the Rio Chama and its tributaries. The ages of the terraces are established by amino-acid dating of fossil land-snail shells (Dethier and McCoy, 1993) and the presence of the Lava Creek B volcanic ash in the highest terrace (Dethier et al.,...
1990), indicating that the Rio Chama valley has been down cut 120 m in the past 640,000 yrs (Dethier et al., 1988). Along the north slope of the lower Oso valley, Dethier and Demsey (1984), Dethier and Manley (1985) and Koning et al. (2005) mapped a Pleistocene gravel deposit that forms a prominent terrace about 42 m above the Oso floodplain; the high Pleistocene gravel is not a part of this investigation.

**RADIOCARBON DATING**

Twenty samples for radiocarbon dating were collected from the thick alluvial section at the south terrace (by RDP) and two from alluvium at the north terrace locality (by SAH) (Table 1). The close-interval samples from the terrace alluvium were analyzed for radiocarbon dating as bulk sediment in which the solid and soluble organic matter was dated. Some of the sediment samples have a high charcoal content, perhaps of cultural origin. The radiocarbon dates were obtained by both conventional and accelerator mass spectrometry (AMS) methods after pretreatment to remove carbonates. The conversion of corrected radiocarbon dates to calendar years is performed by the CALIB rev 5.0.1 program (Stuiver and Reimer, 1993; Reimer et al., 2004). Discussions of geochronology in this study will specify whether radiocarbon years “^{14}C yrs BP,” or dendro-calibrated calendar years “cal yrs BP” and “cal BC/AD,” or true historic ages “BC/AD” are being referred to.

**MODERN CHANNEL AND FLOODPLAIN**

The modern channel-floodplain of Rio del Oso is 90 to 215 m wide in the lower 4 km of the stream valley before it joins the Rio Chama. The floodplain, with various low benches formed by deposition and scouring of the floodplain surface, is about 1 meter above the channel and is vegetated by grasses and small scattered trees of cottonwood, salt cedar, Russian olive, willow, and elm. Water in the Oso flows through the primary (north) channel. During high discharge events, excess water is carried by two connecting channels that are incised through the floodplain deposits. The two ancillary channels are maintained by seasonal flow, originating in the early spring by melt water from snow in the Jemez and in the late summer by runoff from convective monsoonal rainstorms (Fig. 2). The primary channel is 55 to 120 cm deep. During a flood event in August 2006, the floodplain sediments separating the middle channel and north channel were scoured out, merging the two into one wide channel. Sediments in the primary channel consist of very pale brown, fine to very coarse quartz sand, and include basalt clasts ranging from fine to very coarse sand and to granule-cobble-boulder gravels. The

| TABLE 1. Radiocarbon dates, Rio del Oso alluvium, Rio Arriba Co., New Mexico. |
|---|---|---|---|---|
| **Depth (cm)** | **Lab no.** | **Measured^{14}C age** | **Corrected^{14}C age** | **Calibrated age, calendar yr BP** |
| **South Terrace Alluvium (coll. by RDP)** | | | | |
| 18-22 | Beta-104591 | 640 ± 80 | 640 ± 80 | 648, 576 |
| 38-42 | Beta-104590 | 730 ± 70 | 730 ± 70 | 674 |
| 58-62 | Beta-104589 | 950 ± 60 | 950 ± 60 | 910, 844, 806 |
| 88-92 | Beta-104588 | 1100 ± 60 | 1100 ± 60 | 1046, 974 |
| 114 | Beta-104587 | 1520 ± 50 | 1530 ± 50 | 1400 |
| 148 | Beta-104586 | 1710 ± 80 | 1710 ± 80 | 1680, 1607, 1577 |
| 173 | Beta-104585 | 2120 ± 60 | 2120 ± 60 | 2117, 2074 |
| 214 | Beta-104417 | 2930 ± 60 | 3010 ± 60 | 3228, 3174 |
| 239 | Beta-104416 | 2900 ± 50 | 3110 ± 50 | 3352 |
| 249 | Beta-104584 | 2930 ± 50 | 2950 ± 50 | 3136, 3042, 3099 |
| 258 | Beta-104583 | 2810 ± 100 | 2810 ± 100 | 2940, 2903 |
| 264 | Beta-104582 | 3120 ± 60 | 3140 ± 60 | 3370 |
| 278 | Beta-104581 | 3510 ± 60 | 3510 ± 60 | 3827, 3778, 3738 |
| 293 | Beta-104580 | 3570 ± 80 | 3570 ± 80 | 3867 |
| 309 | Beta-104579 | 3800 ± 50 | 3800 ± 50 | 4213, 4173, 4156 |
| 319 | Beta-104415 | 4000 ± 60 | 4230 ± 60 | 4832 |
| 348 | Beta-104578 | 3780 ± 50 | 3760 ± 50 | 4145, 4117, 4098 |
| 358 | Beta-104577 | 2780 ± 100 | 2780 ± 100 | 2914, 2867 |
| 399 | Beta-104414 | 4520 ± 60 | 4610 ± 60 | 5428, 5315 |
| 459 | Beta-104576 | 3540 ± 50 | 3540 ± 50 | 3846, 3784 |
| **North Terrace Alluvium (coll. by SAH)** | | | | |
| 105-110 | Beta-224146 | 1990 ± 50 | 2060 ± 50 | 2028, 2002 |
| 165-170 | Beta-104419 | 2540 ± 50 | 2630 ± 50 | 2752 |

A = material dated is bulk sediment except Beta-104419 that is charcoal
B = radiocarbon ages with asterisk (*) are by AMS; others by conventional radiocarbon; Libby half life (5568 years)
C = \(^{14}C/^{12}C\) ratios not determined and radiocarbon age not corrected where \(^{14}C\) values not given
D = intercept of radiocarbon age with calibration curve, ages in calendar years BP (0 yr BP = AD 1950); calculated by CALIB Rev 5.0.1 (Stuiver and Reimer, 1993; Reimer et al., 2004)
sand grains are subrounded, poorly sorted, and form weak laminae and some small crossbeds in floodplain deposits adjacent to the channel.

**HOLOCENE TERRACE**

Only one Holocene terrace is preserved in the lower Rio del Oso valley, and it is composed of late Holocene overbank and channel deposits of fine quartz sand. Field surveying shows that the terrace on the north side of the valley is 3 m above the modern channel, while the terrace on the south side is 5 m above the present channel (Fig. 2). The slope of the terrace surface, with the south terrace surface higher than the north terrace surface, parallels the slope of the modern channel-floodplain, indicating that the fluvial-geomorphic process that resulted in the north-sloping Holocene valley fill remains active today. The radiocarbon age of the north and south terrace alluvium is the same (discussed below).

**ALLUVIAL STRATIGRAPHY**

The late Holocene alluvium of the lower Rio del Oso consists of 3 to 5 m of fine to very fine and medium quartz sand with a number of cumulic A-horizon paleosols. Upstream, the valley narrows and the terrace and late Holocene alluvium are largely removed by erosion except for local terrace remnants. The age of the alluvial deposits ranges from 4600 to 640 $^{14}$C yrs BP, based on 22 radiocarbon dates. After 600 $^{14}$C yrs BP, fluvial aggradation in the valley halted, and, subsequently, the valley fill was incised and largely removed, forming the Holocene terrace.

**Basal gravels**

Underlying the late Holocene alluvial sand is pebble-cobble-boulder sandy gravel composed largely of basalt clasts derived from upstream outcrops of the Lobato basalt (Fig. 3). The basalt gravel at one time extended across the valley. The top of the gravels exhibit an absence of soil development and may be eroded. The late Holocene fine-grained alluvium was deposited on the eroded surface of the gravels. Today, the modern channel of the Oso is downcut into the gravel, exhuming large basalt clasts that have been incorporated in the historic floodplain and channel deposits.

**South terrace alluvium**

The late Holocene alluvium is a massive light brown-pale brown-yellowish brown fine to very fine quartz sand with small amounts of silt and clay but without gravel (Table 2). The south
terrace alluvium is 470 cm thick and rests directly on undated channel sands and basalt gravel. The sediment is soft, well sorted, and lacks any trace of visible bedding or erosional unconformities. The sediment is weakly to moderately calcareous with 2 to 4% calcium carbonate probably derived from local calcareous sandstone bedrock. Visible carbonates are generally lacking although occasional faint carbonate filaments are present; thin carbonate coats are generally less than 5% of sand grain surfaces. The south terrace stratigraphic sequence was deposited in a slowly aggrading floodplain environment and incorporates a remarkable succession of seven cumulic A paleosols (Figs. 4, 5). The age and sedimentation rate of the south terrace alluvium are documented by 20 radiocarbon dates. Four distinct horizons of archaeological features are also found in the alluvium. Numerous cicada insect burrow fills 6 to 18 mm wide occur throughout the sediment column; individual burrows can be traced as much as 10 cm (Fig. 6).

North terrace alluvium

The north terrace alluvium differs considerably in detail from the sequence on the south side (Fig. 7). The north terrace alluvium is light yellowish brown to very pale brown medium-fine-coarse quartz sand and silty sand and lacking gravels. The alluvial sand is 305 cm thick and rests directly on undated basalt gravel; the gravel/sand contact is an erosional unconformity. The lower half of the alluvium below approximately 135 cm is poorly sorted sand with several layers of clayey silt 1 to 5 cm thick, all exhibiting laminae and small crossbeds. The bedded sand is strongly calcareous with carbonate filaments; bioturbation is largely absent. The upper 135 cm is medium to fine quartz that is massive, lacking primary bedding. One 25 cm-thick cumulic A paleosol occurs in the massive sand at about 1 m depth. The alluvium above the paleosol is marked by numerous burrow fills and rodent-carnivore bioturbation. The poor sorting, alternating sand and silt layers, and presence of laminae and cross beds together indicate floodplain and channel-related sedimentation during deposition of the lower half of the sequence. The upper half of the sequence is characterized by massive unbedded sand and the cumulic paleosol indicating overbank sedimentation. During the late Holocene, the Rio del Oso channel may have been closer to the north side of the valley than the south, similar to the situation today.

CUMULIC A-HORIZON PALEOSOLS

One of the remarkable aspects of the Oso alluvial record is the presence of seven cumulic A horizon paleosols, ranging from 5 to 62 cm thick and representing collectively 41% of the south terrace stratigraphic record. The paleosols are all developed in fine to very fine quartz sand and are very dark grayish brown to brown and, in contrast to the light brown sand between paleosols, are visibly prominent in outcrop exposures because of their dark color. The dark color of the paleosols is due to levels of organic carbon, 0.33 to 0.54%, that are twice the amount found in nonpaleosol sediment (Fig. 8; Table 1). None of the paleosols exhibit secondary pedogenic B horizon properties. The paleosols are moderately calcareous, some carbonates occurring as filaments that follow small roots, although the paleosols are generally no more calcareous than are the intervals of sandy alluvium between paleosols. The basal and top boundaries of the paleosols are commonly obscured by cicada insect burrow fills that have mixed the

### TABLE 2. Sediment data from late Holocene alluvium, South Terrace locality, Rio del Oso, Rio Arriba Co., New Mexico; numbers are percentages; Wentworth scale; Munsell Soil Color Chart.

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>DEPTH (cm)</th>
<th>SAND (mm)</th>
<th>RECALCULATED SAND</th>
<th>SILT</th>
<th>CLAY</th>
<th>&lt;0.045</th>
<th>OC</th>
<th>CaCO₃</th>
<th>DRY COLOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Terrace alluvium</td>
<td>15-20</td>
<td>0.0 0.1 14.9 60.8 24.2</td>
<td>87 6 7 0.27</td>
<td>2.0</td>
<td>10YR 4/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33-38</td>
<td>0.0 0.2 11.1 58.4 30.3</td>
<td>86 6 8 0.19</td>
<td>2.4</td>
<td>7.5YR 4/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleosol G</td>
<td>71-76</td>
<td>0.0 0.2 14.5 59.7 25.6</td>
<td>83 8 9 0.33</td>
<td>3.0</td>
<td>7.5YR 4/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>89-94</td>
<td>0.0 0.1 14.9 58.9 26.1</td>
<td>82 8 10 0.40</td>
<td>2.8</td>
<td>7.5YR 4/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-paleosol</td>
<td>120-125</td>
<td>0.0 0.1 13.3 61.5 25.1</td>
<td>83 7 10 0.22</td>
<td>3.0</td>
<td>10YR 5/3</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>140-145</td>
<td>0.0 0.2 13.3 62.8 23.7</td>
<td>87 5 8 0.15</td>
<td>2.3</td>
<td>10YR 4/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleosol F</td>
<td>170-175</td>
<td>0.0 0.2 16.0 62.5 21.3</td>
<td>85 8 7 0.35</td>
<td>2.0</td>
<td>10YR 3/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>200-205</td>
<td>0.0 0.4 17.5 60.0 22.1</td>
<td>82 9 9 0.41</td>
<td>2.1</td>
<td>10YR 3/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-paleosol</td>
<td>265-270</td>
<td>0.0 0.2 19.1 61.9 18.8</td>
<td>89 5 6 0.06</td>
<td>2.0</td>
<td>7.5YR 6/4</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Paleosol D</td>
<td>295-300</td>
<td>0.0 0.5 17.9 58.1 23.5</td>
<td>77 9 14 0.54</td>
<td>3.8</td>
<td>10YR 3/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

"0.0" = measured but zero percent; OC = % organic carbon (Walkley-Black); % carbonates determined by chittick method; sedimentology by Milwaukee Soil Laboratory, 6917 W. Oklahoma Ave., Milwaukee, Wisconsin 53219

CUMULIC A-HORIZON PALEOSOLS
dark paleosol and the lighter-colored nonpaleosol sediment. The
seven paleosols are labeled A through G from the bottom to top
of the sequence (Fig. 5).

One cumulic A horizon paleosol occurs in the upper alluvial
sequence at the north terrace (Fig. 7). A single radiocarbon date,
2060 ± 50 \(^{14}C\) yrs BP, indicates that it correlates to paleosol F in
the south terrace. Paleosol F, thickest of the paleosols (62 cm),
may have been a valley-wide floodplain soil, while the others
were only local in extent. The age of paleosol F is ca. 3000 to
2000 \(^{14}C\) yrs BP. Farther downstream along the bank of the north
terrace, paleosol F is eroded and missing although another cumu-
lic paleosol, undated, occurs at a stratigraphically lower position
in the terrace alluvium.

Carbon isotopes

The cumulic paleosols with their comparatively high organic
carbon content likely represent floodplain soils characterized by
grasses and sedges. Inspection of the \(\delta^{13}C\) values from the radio-
carbon dates (Table 1), however, shows that the organic matter
present in the paleosols and nonpaleosol alluvium has \(\delta^{13}C\) values
of -19.7 to -25.9‰ that are characteristic of \(C_3\) plants; only two
samples with \(\delta^{13}C\) values of -11.0 and -12.4‰ suggest a domi-
nance of \(C_4\) grasses and wet-meadow plants (Boutton, 1991). If
the carbon isotopes are significant and representative, the organic
carbon content of the alluvium and paleosols is derived primarily
from grasses, herbs, shrubs, and trees in the upland landscape and
less from wet ground plants on the floodplain.

Atmospheric silt influx

While the chronology of the alluvial sequence at the south ter-
race is well established, insufficient geochronologic control exists
to determine differences in sedimentation rates between paleo-
sol and nonpaleosol alluvium. Nevertheless, it has been shown elsewhere that cumulic A paleosols are a result of periods of slowed sedimentation (Hall, 1990a). At Oso, the paleosols have higher percentages of silt than does non-paleosol alluvium (Fig. 8). Canyon streams on the Pajarito Plateau carry abundant silt (Malmon et al., 2004). However, in Oso alluvium the percentages of silt and very fine sand are unrelated (Table 2); if the silt were fluvial in origin, the high percentages of silt would correspond to higher amounts of very fine sand, a situation that is not the case. Thus, the data suggest that the elevated amounts of silt in the paleosols are eolian in origin. An eolian silt component of soils has been documented elsewhere (Eberly et al., 1996; Reneau et al., 1996; Muhs and Benedict, 2006).

SEDIMENTATION RATE

A remarkable series of 20 radiocarbon dates from 4.7 m of massive overbank alluvium shows a near-uniform sedimentation rate for a period of 5000 cal yrs at Oso (Table 1). A net rate of sedimentation of 0.075 cm per calendar year has been determined by linear regression of depth versus age in calendar years BP of the thick alluvial section at the south terrace (Fig. 9). The correlation coefficient is strong, $r = 0.98$. Three incongruous radiocarbon dates (discussed below) were omitted from the sedimentation rate calculations.

Close inspection of the plot of depth versus age shows that the three uppermost ages indicate a more rapid net sedimentation rate in the upper meter of the south terrace alluvium since about 1000 cal yrs BP. We interpret this departure from the net sedimentation rate as a consequence of the increased influx of colluvial sand from the immediately adjacent hillslope above the terrace to the site of floodplain deposition. The increase in sedimentation rate and possible increased sheet erosion rates may be due to local changes in climate and vegetation. Late prehistoric agriculture, fuel harvesting, and general land use by puebloans in the immediate area may have contributed as well to increased sheet erosion and valley sedimentation.

STRATIGRAPHICALLY REVERSED RADIOCARBON DATES

Linear regression analysis of the large number of radiocarbon dates on bulk sediment from the south terrace allows us to identify three stratigraphically reversed dates that, because of their magnitude, cannot be explained by cicada bioturbation. The incongruous dates (Beta-104578, -104577, -104576) are all younger than their stratigraphic position would indicate by ca. 500, 1900, and 2300 cal yrs, respectively. The stratigraphic equivalents of these incongruous ages are approx. 40, 140, and 170 cm of vertical section or depth. There is no apparent explanation for the disharmonious dates. It should be pointed out, however, that the ability to
recognize coarse-scale stratigraphic-age inversion of radiocarbon dates is only possible in this case because of the large number of dates from successive stratigraphic levels. If, instead, only a few radiocarbon dates had been obtained from widely spaced intervals, erroneous dates, if any, might not be identified.

CORRELATION OF OSO ALLUVIAL RECORD

The Rio del Oso valley fill consists of undated basalt gravels overlain by 3 to 5 m of late Holocene alluvium dated between 4600 and 600 $^{14}$C yrs BP. Early Holocene sediments are missing from the local record, unless represented by the underlying basalt gravel. The late Holocene alluvium is massive fine quartz sand and does not exhibit erosional unconformities although it contains a number of cumulic A horizon paleosols.

Recent studies on the Pajarito Plateau focus on alluvial terraces and soils developed on the terraces and provide a valuable basis for comparison with the Rio del Oso record. In Ancho and Sandia canyons, sequences of alternating floodplain and channel deposits represent a period of general aggradation between 4900 and 1200 $^{14}$C yrs BP (Reneau and McDonald, 1996, p. 46-48, 68-69). In contrast, rapid downcutting in Rendija Canyon has led to a series of stepped terraces, each inset into and at lower elevation than the other. The four younger terraces are Holocene. Basal sediments from the Qt5 terrace are dated 8800 and 8900 $^{14}$C yrs BP at two different localities, sediment in the 5 m-high Qt6 terrace is dated 6900 to 5200 $^{14}$C yrs BP, the inset younger 3 m-high Qt7 terrace is dated 3200 $^{14}$C yrs BP, and the youngest terrace Qt8, which forms the canyon floor about 1 m above the modern channel, is dated 1580 to 490 $^{14}$C yrs BP (Reneau and McDonald, 1996, p. 118; McDonald et al., 1996). The late Holocene alluvial records from Ancho and Sandia somewhat match that from Oso: fluvial sedimentation beginning ca. 5000 $^{14}$C yrs BP and ending after 1200 $^{14}$C yrs BP. The Rendija Canyon record of deposition and downcutting seems anomalous, however, and may be a response to local fluvial conditions not found at Ancho, Sandia, or Oso.

The Oso record of channel incision after 600 $^{14}$C yr BP is unusual. Except for some cases from the Jemez area (Reneau and McDonald, 1996; McDonald et al., 1996; Riihimaki and Dethier, 1998), other alluvial records in the south-central and southwestern United States show widespread channel erosion beginning 1000 $^{14}$C yrs BP, and most of these records, such as Chaco Canyon, Zuni, and Tesuque, show renewed alluvial deposition by ca. 800 $^{14}$C yrs BP (Miller and Wendorf, 1958; Hall, 1977, 1990a, b), very different from the Oso record (Fig. 10).

OSO ALLUVIUM AND PAST CLIMATE

One of the grand issues in geomorphology concerns the relationship of fluvial aggradation and downcutting to climate and climate change. It is generally agreed that climate is the primary influence on fluvial processes and stream history in the Jemez Mountains (Reneau, 2000). Local stream histories of aggradation and incision in the Jemez exhibit a great deal of variability. For example, the multiple episodes of Holocene incision and terrace formation in Rendija Canyon have been interpreted as the consequence of unusually high magnitude flood events (Reneau and McDonald, 1996, p. 140). In contrast, the alluvium in Ancho Canyon, Sandia Canyon, and Rio del Oso indicate floodplain deposition during the late Holocene without evidence of high
magnitude flood events or downcutting. As indicated by Reneau (2000), however, Jemez stream histories are variable, the differences related to local conditions. We suspect that the Rendija Canyon record is indeed a local case and that the alluvial records of Ancho, Sandia, and Oso are more representative. Regardless, further studies of alluvial stratigraphy, sedimentology, and geochronology will allow us to differentiate streams that are responding predominantly to local conditions versus streams that are responding to a broader pattern of Jemez climate.

One emerging pattern suggests that the alluvial history of the Jemez Mountains differs from that of the broader region, especially for the late Holocene period where numerous high-resolution records are in hand. The episode of erosion about 1000 $^{14}C$ yrs BP that characterizes the southwest and southern plains evidently did not occur everywhere in Jemez mountain streams. Instead, downcutting of the Oso valley occurred after ca. 600 $^{14}C$ yrs BP at a time when other alluvial valleys in the greater Southwest were aggrading. The regional downcutting documented about 1000 $^{14}C$ yrs BP is a response to a broad-based change in climate from comparatively moist to dry conditions (Hall, 1990a). The continued alluviation at Oso suggests that the local climate of the Jemez Mountains may have continued to be comparatively moist and was not significantly affected by the regional shift to drier conditions that occurred elsewhere about 1000 $^{14}C$ yrs BP.

**ARCHAEOLOGY**

The archaeology of the Oso-Chama area is moderately well known; a large number of preceramic and ceramic-age sites have been documented in the Oso valley (Anschuetz, 1998). Virtually all of these sites occur on old eroded surfaces and lack stratigraphic context, making them nearly impossible to date. The discovery of in situ prehistoric cultural features in the Oso alluvium provides a unique opportunity to obtain radiocarbon ages of the prehistoric occupation of the valley, especially for sites from the Archaic period where diagnostic ceramics are absent.

In this study, five individual cases of buried prehistoric features are radiocarbon dated from ca. cal 3500 BC to 800 BC (Table 3). The dated features occur in both north and south terrace alluvium and are buried at 2 to 4 m depth. The features are mostly hearths with associated charcoal and burned rock. Four features occur in the south terrace alluvium and are stratigraphically distinct from each other, each representing a different site of different age. While artifacts were not observed in place, numerous flakes of obsidian and chert are present on talus slopes below the features. Other buried archaeological features were observed in the Oso alluvium elsewhere but were not studied.

The abundance of buried sites indicates that the Oso valley has been a focus of occupation by prehistoric people during at least the past 5500 cal yrs. More recently, between ca. AD 1250 and 1600, several pueblos were constructed along the Chama River valley and its tributaries including the Rio del Oso (Hewett, 1906). Agricultural fields may have been present on the lower Oso floodplain but are now eroded away by downcutting. On a south-facing slope formed by Pleistocene gravels above the Oso, stone-lined agricultural fields were planted in corn and cotton sometime during the period ca. AD 1250 to 1500 (K. Anschuetz, G. Dean, personal commun., 2007). The Oso-Chama valley was intensely occupied during the past millennium by pueblos and, later, the Spanish. The relationship of cultural activities to the
surface processes in the Oso valley of alluviation and downcutting has been addressed by Periman (2005).

**Late prehistoric irrigation farming**

Our conclusion that the Jemez Mountains may not have been significantly affected by the climate shift to drier conditions ca. AD 1000 and that some Jemez streams may have continued to aggrade without downcutting at that time has strong implications for local prehistoric farming. If regional streams were downcutting after AD 1000 but some Jemez streams were not, Jemez area floodplains could be used for agriculture, including irrigation, continuously without the interruption that affected other areas (Damp et al., 2002). The fine sand of the comparatively wide floodplain of the Oso would have been a good substrate for agriculture. After ca. AD 1400, however, downcutting of the Oso, and possibly other streams in the Jemez area, would have dramatically affected the local practice of irrigation agriculture.

**CONCLUSIONS**

The remarkable Rio del Oso alluvial record with its slow rate of aggradation, cumulic soils, absence of erosional unconformities, abundance of buried archaeological sites, and late persistence of its alluviation, may all be related to its comparatively large, high-elevation watershed and near-permanent year-round flow. The local mesic climate of the Jemez Mountains has evidently resulted in stream behavior that exhibits a great deal of variability as well as alluvial chronologies of erosion and deposition that are unlike alluvial sequences elsewhere in the greater Southwest. The generally mesic late Holocene climate may also have played a role in late prehistoric irrigation agriculture in the Oso-Chama valley.

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