Modeling Landscapes and Past Vegetation Patterns of New Mexico's Rio Del Oso Valley

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Humans have interacted with the landscape and ecosystem of New Mexico's Rio del Oso Valley for thousands of years. Throughout the Holocene, various cultures have dramatically affected and altered the Rio del Oso. An interdisciplinary research approach, incorporating geomorphology, paleobotany, archaeology, and history, provides a broad range of methodologies and data sets of past landscape dynamics. Integrating such data sets in three-dimensional Geographical Information Systems (GIS) models of past vegetation and landscape conditions may enable a view of anthropogenic ecosystem change. Analyses of past land use through landscape models, geoarchaeology, and other methods can provide a greater understanding for current and future ecosystem management. © 2005 Wiley Periodicals, Inc.*

INTRODUCTION AND ARCHAEOLOGICAL BACKGROUND

Landscape history and geoarchaeology may be applied in a forum that integrates concerns regarding the management of ecosystems. Since the end of the Pleistocene, humans have manipulated and domesticated global resources, transforming the world into a system of interconnecting and overlapping cultural landscapes (Edwards, 1988; Simmons, 1988; Norton, 1989; Caseldine and Hatton, 1993). Interactions between human cultures and environments have induced worldwide ecological change. Historic and current industrial activities produce measurable increases in carbon dioxide, greenhouse gases, and inorganic and organic nitrogen (Rossignol and Wandsnider, 1992; Willey and Sabloff, 1993, Schmidt, 1998; Vitousek et al., 1997). Culturally induced environmental changes are compounded by increased occurrences of flooding, prolonged drought, and possible famine (McIntosh et al., 2000). On a global scale, scientific analyses of environmental change suggest that the momentum of alterations in ecological processes continues to accelerate (Schmidt, 1998; Vitousek et al., 1997).

Hunter-gatherers initiated cumulative processes of broad-scale environmental change, influenced biodiversity, and maintained a heterogeneous landscape mosaic with the use of controlled burns over thousands of years, as evidenced by pollen and charcoal-particle analyses (Delcourt and Delcourt, 1996). In the Peruvian Andes,

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paleobotanical research shows widespread deforestation and burning to clear land for agriculture 4000 years ago (Chepstow-Lusty et al., 1998). In the Appalachian Mountains of North America, the landscape was managed during the late Holocene with the cultivation and systematic care of chestnut oak (*Quercus prinus*) forests (Delcourt and Delcourt, 1997; Delcourt et al., 1998). Along the coastal areas of the Americas, indigenous peoples altered forests, grasslands, wetlands, and river valleys. The introduction of intensive European agriculture and industry in existing Native American ecosystems superimposed further change and conflict onto landscape histories (Whitmore and Turner, 1990:416; Mannion, 1991; Deneven, 1992:370).

Human-induced changes in ecoprocesses, such as agriculture and controlled burning, affect plant-community composition, habitat area, and carbon, nutrient, water, and decomposition cycles. Changes in ecosystem processes, vegetation patterns, and geomorphology create variations in the configuration of landscape components (Hobbs, 1997). Fossil-pollen assemblages, microscopic charcoal, and faunal extinctions are indications of human-induced ecological change (Chambers, 1993a, 1993b; Walker and Singh, 1993). Knowledge of previous ecological conditions and capacities can be incorporated into environmental restoration and planning by land managers.

Cultural and paleoecological landscape approaches were integrated to reconstruct the environmental history of the Rio del Oso Valley, a tributary of the Rio Chama River, in north-central New Mexico, U.S.A. Human occupation has affected the conditions of the current Rio del Oso ecosystem. Cultural and ecological landscape interactions in the Rio del Oso have varied through time, from hunter-gatherers, pre-Columbian farmers, Hispanic ranchers, and commercial grazing pressures. Interdisciplinary methods identified cumulative anthropogenic effects, and provided the data sets used to reconstruct a long-term ecological history of the valley. Visual models of past landscape vegetation were created using Geographical Information Systems (GIS).

A set of definitions for ecosystems and anthropogenic landscapes that incorporate cultural and ecological environmental concepts were integrated in this Rio del Oso paleolandscape study. An ecosystem is "composed of physical-chemical-biological processes active within a space-time unit of any magnitude, i.e., the biotic community plus its abiotic environment" (Lindeman, 1942:400). An ecological landscape is a spatial matrix consisting of organisms, populations, and ecosystems (Allen and Hoekstra, 1992:56). Anthropogenic, cultural landscapes are formed within, and are integral to, ecological spatial matrices; this includes process as well as form, both changing through time. New anthropogenic landscapes are created within, and as part of, the ecosystem and spatial matrix.

The Rio del Oso Valley contains a rich archaeological record, resulting from over 7000 years of human occupation. During the Archaic period (5500 B.C.–A.D. 600), hunter-gatherers in the valley dispersed seeds, selectively harvested plant and animal species, and used controlled burns to increase vegetative resource yields. Archaic archaeological data has been buried under 1–2 m of sediment, but significant arroyo erosion has enabled site discovery. Between the late Archaic and the Coalition period (A.D. 600–1200), there was less human occupation (Anschuetz, 1995), although archaeological evidence may simply remain buried, or unexposed by erosion.

Between 1200 and 1600 A.D., Puebloan groups built villages and agricultural features, causing significant landscape change in the Rio del Oso (Anschuetz, 1995). These activities placed selective pressures on local vegetation and animal populations. Puebloans cleared land for agriculture, constructed fields and rain conservation structures, built carved terraces with cobble-mulch gardens to conserve water, and collected wood resources for fuel and construction. In the 1600s, Spanish settlers superimposed their own landscape patterns over those created by the Puebloans (Wozniak et al., 1992). They used existing pueblos, constructed roads, farms, and fortified settlements, and built systems of agricultural water ditches called *acéquias*. In the early 20th century, the U.S. Department of Agriculture, Forest Service, assumed administration of the area, adding another pattern of human use and environmental change.

GEOLOGY OF THE RIO DEL OSO

The Rio del Oso is a perennial stream, fed by snow melt, rainfall, and springs. Its narrow watershed begins in the volcanic Jemez Mountains in north-central New Mexico, on the northern slope of Chicoma, the highest peak at an elevation of 3524 masl. The headwaters of the Rio del Oso drainage originate in the Tschicoma Formation dacite. The northeastern margin of the Jemez consists of a series of extrusive flows and domes of late Tertiary volcanic rock (Dethier et al., 1988). The lower Rio del Oso Valley cuts into the indurated Ojo Caliente sandstone of the Tesuque Formation, late Tertiary Santa Fe Group. Exposed across the lower Oso Valley are north–south trending dikes of black Lobato Basalt (Dethier and Demsey, 1984). Pleistocene gravels occur at various elevations along the Rio Chama's valley margins, overlaying eroded Tertiary bedrock. This represents former channel and floodplain positions of the Rio Chama and its tributaries.

Gravel terraces indicate that the Rio Chama valley has cut down 120 m during the past 600,000 years (Dethier et al., 1988; Dethier and Reneau, 1995). Pleistocene gravel deposits form a prominent terrace along the north slope, about 43 m above the Rio del Oso's low floodplain. The Rio del Oso flows 26 km northeast through the Jemez, dropping to 1743 masl, where it enters the Rio Chama River at the settlement of Chili. At this confluence, the watershed is less than 3 km across. The vegetation in Rio del Oso Valley consists of an Engelmann spruce (*Picea engelmannii*) cork bark fir forest at high elevations, Ponderosa pine (*Pinus ponderosa*), and Douglas fir (*Pseudotsuga menziesii*) at mid-elevations, and pinyon pine (*Pinus edulis*), juniper (*Juniperus monosperma*) woodlands, and juniper-shrub grasslands at lower elevations. Cottonwoods (*Populus fremontii*), aspen (*Populus tremuloides*), willow (*Salix exigua*), and other riparian vegetation are found in the stream bottoms (Figure 1). The surrounding mesas and terraces support a variety of mixed grasses, shrubs, and cacti. Although cryptogamic crusts provide some protection, plant cover is sparse, and underlying sandy sediments are exposed and vulnerable to erosion from wind and rain. Weather records from Los Alamos County show that annual rainfall ranges from 89 to 28 cm, from the high to low elevations of the eastern Jemez mountain slopes (Reneau et al., 1996). Along the lower, northern portion, the drainage is bordered by five mesas separated by deeply incised arroyos, which remain dry much

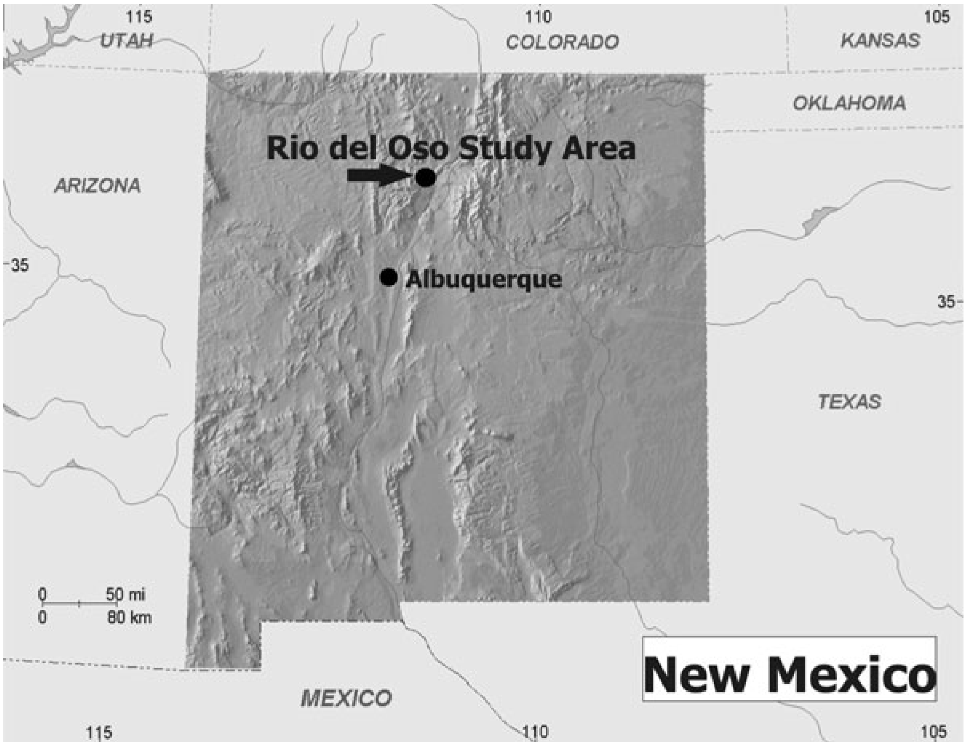

Figure 1. Study area in the lower portion of the Rio del Oso watershed, northern New Mexico.

of the year. Although heavy seasonal rains flood the arid tributaries, the water rapidly drains away, leaving little moisture behind. The southern edge of the valley is etched by erosion, deep arroyos, and colluvial slopes.

The Rio del Oso floodplain has low terraces formed by deposition and scouring, currently 90–215 m wide in the lower 4 km of the stream valley, ending at the Rio Chama confluence. These terraces are approximately 1 m above the channel margin, and vegetated by grasses and scattered cottonwood, salt cedar (*Tamarix ramosissima*), Russian olive (*Elaeagnus augustifolia*), willow (*Salix exigua*), and elm (*Ulmus spp.*) trees. During intermittent periods of consistent flow in the Rio del Oso, water runs 55–120 cm deep, through two connecting channels incised in the floodplain deposits. Alternate channels occur seasonally, from snow meltwater in the Jemez Mountains during early spring and runoff from summer thunderstorms and monsoon rainstorms (Periman, 2001).

The sediments in the main channel of the Rio del Oso are composed of coarse quartz sand and gravel-sized clasts of basalt. The sand in this main channel is medium to quite coarse, pale brown in color, and contains basalt clasts; ranging from fine, to very coarse sand, and to granule-cobble-boulder gravels. The grains are subrounded, poorly sorted, and include carbonate-cemented sand aggregates about 1 mm in diameter, which form weak laminae and small crossbeds in floodplain deposits adjacent to the channel (Periman, 2001).

METHODOLOGY

The calibration of the fossil-pollen spectra from the Rio del Oso used pollen surface samples from modern vegetation communities and plant-density ratios in reconstructing models of past plant abundances. The relationship between vegetation and pollen assemblages are influenced by pollen production, dispersal patterns, deposition, preservation, and identification (Davis, 1963; Birks et al., 1988, Jackson, 1994). These processes are influenced by physical, chemical, biological, and behavioral factors (Sugita, 1994). Temporal and spatial variations affect comparison of corresponding pollen and plant assemblages. Mathematical models of pollen-vegetation relationships were defined with the ratio between pollen and vegetational percentages, described as a taxon's R-value (Davis, 1963; Webb et al, 1981; Prentice and Parsons, 1983).

Analytical reconstruction of past environmental conditions in the Rio del Oso used analogues of current vegetation communities and ecosystems. Fossil-pollen assemblages represent the composition of vegetation that may have surrounded the site at the time of deposition (Jackson and Kearsley, 1998; Jackson, 1994). This pollen analysis used production and dispersion indices before the percentages derived from the pollen data to estimate past forest compositions. Variations in pollen assemblages corresponded with observable variations in vegetation composition. Comparable pollen-vegetation relationships in R-value calibration of pollen production and pollen-to-plant ratios estimated past and current plant abundances. Interpretation of pollen data provided indicators of the magnitude of vegetational population and change through time (Andersen, 1970; Birks and Gordon, 1985:202–204).

Preliminary fieldwork began in 1996, with the collection of sediment samples from a 5-m, exposed section of stratified alluvial deposits (Section A). The vertical arroyo wall was cleaned and faced using hand tools. Pollen, phytoliths, microscopic charcoal, and samples for radiocarbon dating were extracted from 24 strata defined by color and sediment composition. Prehistoric, archaeological hearth features were uncovered during preparation of the vertical section, and bulk sediment samples were radiocarbon dated. In 1999, another section (B), located 130 m east of Section A, was excavated with a backhoe. Here, an 8-m profile of alluvium was sampled for pollen, phytolith, microscopic charcoal, and datable material, and 17 strata were defined by color and sediment composition. Residues of pollen, phytoliths, and microscopic charcoal were concentrated from both Sections A and B (Periman, 2001). A third profile, Section C, located on the north side of the drainage, also was sampled. However, only paleobotanical residues from Sections A and B were used for landscape reconstructions due to their locations within contiguous remnant sediments.

Extended pollen and phytolith counts of 400+ grains were obtained for the majority of the samples. Exceptions include phytolith samples 6, 7, 8, and 9 from Section A, which contained very few phytoliths, and pollen samples 16 and 17, near the base of Section B, did not yield sufficient pollen to reach a 400-grain count, and were excluded from further analysis. The pollen record was divided into zones based on cluster analysis. Microscopic charcoal particles were counted in size categories of 5–10 µm, 10–25 µm, 25–50 µm, 50–100 µm, and >100 µm. The number of particles and the geometric mean of the total area of the charcoal particles within each size-class were calculated to determine cross-sectional areas (Delcourt and Delcourt, 1996; Paterson et al., 1987).

In 2000, a stratified sampling strategy was used to identify two suitable surface sample plots within areas of four different vegetation types in order to calculate pollen and vegetation ratios. These areas included grassland, juniper grassland, juniper-pinyon grassland, and cottonwood-willow riparian habitats. After identifying specific areas, random Global Positioning Systems (GPS) coordinates were used within the range of the vegetation polygons to select the southeast corners of the sample plots.

Each sample plot measured 50 × 50 meters, delineated within a 10-m grid. Surface soil samples were taken at each 10-m intersection within the grid, for later analysis of pollen, phytoliths, and charcoal. The vegetation was identified, measured, and quantified using the point-centered quarter method (Cottam and Curtis, 1956:455). The mean distances determine mean area and density per unit area. All other absolute measures were computed from the density per unit area figure. Total basal area per acre was obtained by multiplying the number of trees-per-acre by the mean basal-area-per-tree. Absolute values for the number of trees and basal-area-per-unit area of any species were determined by multiplying the relative figures for density and dominance by total trees-per-hectare to determine density, and by total basal-area-per-acre to determine dominance (Cottam and Curtis, 1956:457). The measurements of tree species, shrubs, and ground cover at each quarter of each quadrat, and the percentage of exposed soil were quantified. After laboratory analysis, these data were used to calculate R-value calibrations for each of the vegetation types.

Three-dimensional visual reconstructions of past Rio del Oso landscapes were produced using the tree and shrub density figures derived from the surface pollen R-values. A digital elevation model (DEM) was used as the base map. The Santa Fe National Forest, USDA, provided digital vegetation data, land type, watershed coverages, DEMs, and made available all archaeological site records and field maps. With these data sources, GIS was used to develop map layers of vegetation, land forms, watershed, and archaeological sites. The simulations were created using a visual simulation system that can produce three-dimensional landscape perspective scenes as seen through a 35-mm camera with a 50-mm lens, providing definition of up to 14 basic tree and shrub forms, and control of the crown width, height, and trunk diameter.

RIO DEL OSO GEOMORPHOLOGY

The late Holocene alluvium of the lower Rio del Oso consists of 4–8 m of fine sand with intercalated cumulic A-horizon paleosols that are preserved and exposed along a narrow, 5-m-high terrace on the north and south margins of the lower Oso Valley, Section A. Upstream, the valley is narrower and the terrace and late Holocene alluvium have been almost completely removed by erosion, except for an occasional terrace remnant. Radiocarbon dates show that the age of the alluvial deposits range from 4060 B.C. to A.D. 1768. Deposition in the valley slowed after A.D. 1768, the valley fill became incised, and the Rio del Oso channel and floodplain dominated the valley floor, leaving a 5–8-m-high terrace, a remnant of the Holocene fill. Prehistoric river sediments prior to A.D. 1768 have not been identified in any of the remnant alluvium. Slow sediment buildup resulted in the development of seven brown-to-dark, grayish-brown cumulic A-horizon paleosols in Section A, separated by zones of fine sand. Some cumulic paleosols also developed in fine sand. Soil B-horizons, visible secondary carbonates, and chemical weathering are not associated with these cumulic soils. The upper boundaries of the paleosols do not form sharp contacts with overlying fluvial sand due to secondary bioturbation of the sediment. The stratigraphic sequence on the southern side of the Rio del Oso Valley appears to have been deposited continuously, without hiatus, in a slowly aggrading floodplain environment. Evidence of erosion in the 6000+ year sequence, as seen throughout much of the Southwest, is not present.

The alluvium beneath the Holocene terrace on the northern side of lower Oso Valley differs considerably from the sequence on the southern side. In the lower half of this Section C, a light yellowish-brown sand includes layers of clay-silt, exhibiting laminae and small crossbeds, with a single 25-cm cumulic A-horizon paleosols. Radiocarbon dates suggest correlation with palaeosol two on the southern side of the valley. The upper meter of the terrace alluvium is marked by numerous rodent burrows. The presence of laminae and crossbeds, poor sorting, and alternating sand and silt layers indicate higher stream velocity in Section C than was seen in sediments on the southern side of the valley. During the late Holocene, the Rio del Oso channel may have been closer to the northern perimeter of the valley than to the southern, similar to the present situation.

These cumulic soils develop during slow deposition of clastic particles by overbank alluvium or spreading flow. Bioturbation mixes the particles with decomposing plant material, and this process produces an organic-rich A-horizon. During periods of slower deposition, thickened, cumulic A-horizon soils form on floodplains and valley floors.

During the late Holocene, in the slowly aggrading environment of the lower Rio del Oso Valley, seven cumulic A-horizon paleosols, ranging from 5 to 62 cm thick, were formed. The paleosols from the top of the terrace down to the base of the exposure were numbered 1–7, and collectively, they make up 41% of the stratigraphic record. The paleosols developed in fine-to-medium quartz sand are dark grayish-brown (in contrast to the pale brown sand between paleosols), and are visually distinct in the outcrop exposures due to this dark color. The paleosols are moderately calcareous, with some carbonates occurring as filaments following small roots. However, the paleosols are no more calcareous than the sandy alluvium that separates them. None of the paleosols exhibit the secondary pedogenic B-horizon characteristics of weakly developed soils, such as blocky structural or chroma differences. The basal and upper boundaries of the paleosols have been obscured by the fill of rodent burrows and other bioturbation. The paleosols in Section B appear to match those of A, although more exposure of the terrace surface would be needed to substantiate this. The Rio del Oso alluvium has been well dated and documented by present standards; greater chronologic resolution could identify subtle differences in sedimentation rates for paleosols versus nonpaleosols zones.

The net sedimentation rate for Section A is 7.65 cm per century, a low value compared to other alluvial records in the region. As a consequence of slow sedimentation, seven cumulic A-horizon soils formed on the valley floor, between 4060 B.C. and A.D. 1768. Two subtrends in the sedimentation occur in the terrace alluvium. The four ages taken from the upper meter of fill show a relatively rapid net sedimentation rate of 14.3 cm per century between A.D. 950 and 1350, twice that of the overall average for the Rio del Oso terrace. This was preceded by a period of much slower deposition that appears to correlate with a period of drought throughout the Southwest. The stratigraphic interval between 1.15 and 2.15 m has a net sedimentation rate of 4.88 cm per century from 1260 B.C. to A.D. 540.

In alluvial Section A, 20 samples were collected for radiocarbon dating, and 10 were collected from Section B. Section A contained three hearth features. The close-interval samples from Section A were submitted for radiocarbon dating as bulk sediment and the solid organic matter (humus) was dated. The more precise method of accelerator mass spectrometry (AMS) was used for radiocarbon dates in Section B.

PALEOBOTANICAL ANALYSES

The stratified pollen data from Sections A and B were each divided into five pollen zones based on a sum of squares analysis, with four zones representing subsurface pollen deposition, and one zone that originated from five surface control samples. All of the subsurface zones differ substantially in pollen content from the surface samples. Radiocarbon dates placed the base of the subsurface record in Section B at 4060 B.C. and the top of the record at A.D. 1768. Section A dates range from 3515 B.C. at the base to A.D. 1350 at the top of the section. Pollen diagrams were structured to reflect samples of similar vegetation types (Figures 2 and 3).

For the surface samples, pollen concentrations in the samples were approximately 17,000–25,000 pollen grains per cc of sediment. The samples collected in the blue grama (*Bouteloua gracilis*) grassland with sparse oak (*Quercus gambelii*) included moderate quantities of juniper and pine pollen, and elevated quantities of oak, sagebrush (*Artemisia tridentate*), and grass pollen (Figure 4). Pollen concentrations are considered high when they reach approximately 50,000 pollen grains per cc (Scott Cummings, 2001). A visual comparison shows that the pollen samples from blue grama grasslands are most similar to each other. Using the same quantitative method, samples from juniper with blue grama grass community display similarities to one another; and samples from juniper with pinyon community resemble each other. Samples from the juniper with blue grama grass vegetation type exhibited slightly elevated juniper and pine pollen frequencies compared to the blue grama grassland samples. High-spine *Asteraceae*, Chenopodium (*Chenopodium spp.*) and amaranth (*Amaranthus spp.*) pollen frequencies were elevated, while sagebrush and grass pollen frequencies were depressed in these areas.

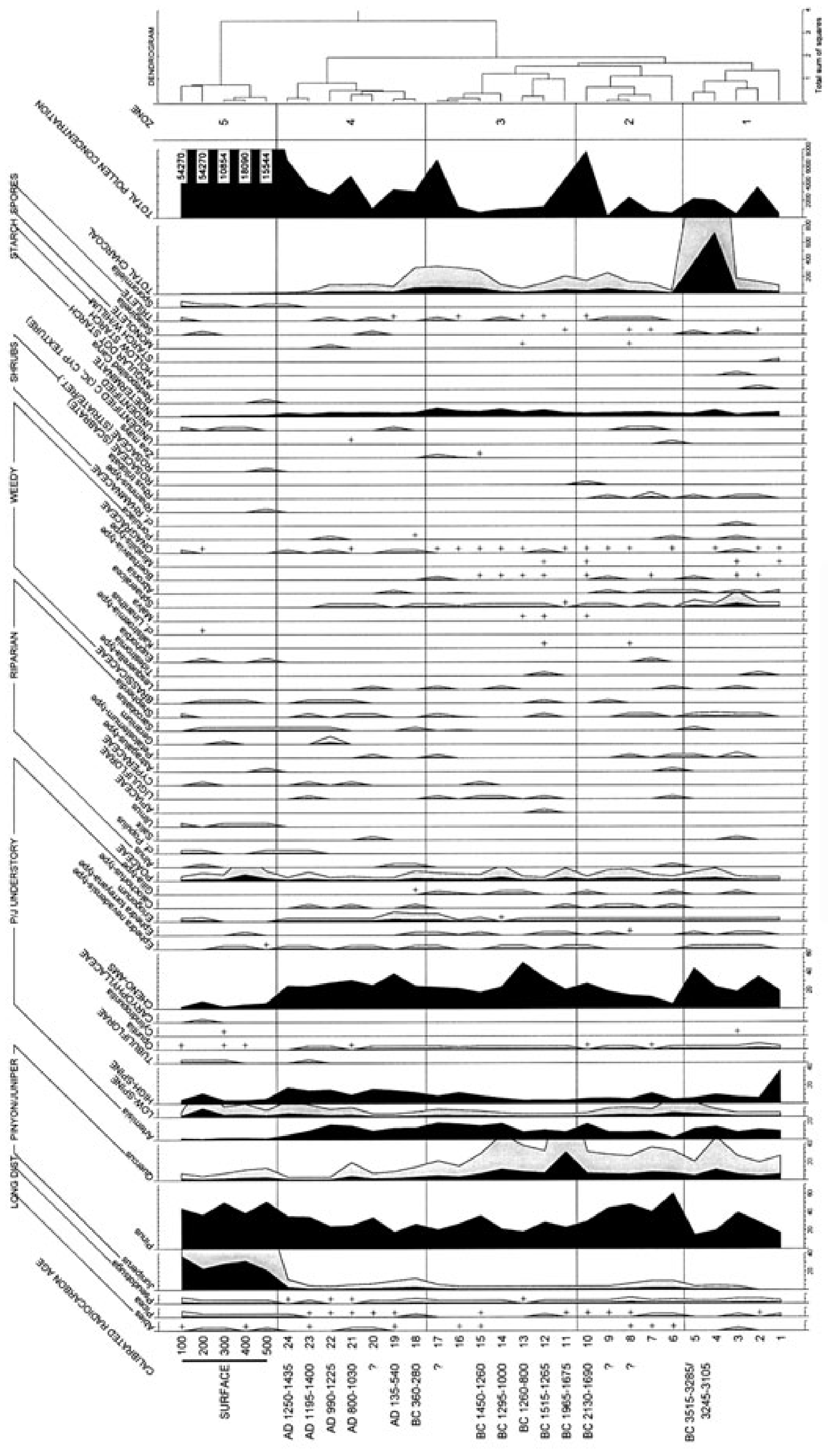

Figure 2. Section A pollen percent diagram, charcoal shown as particle counts.

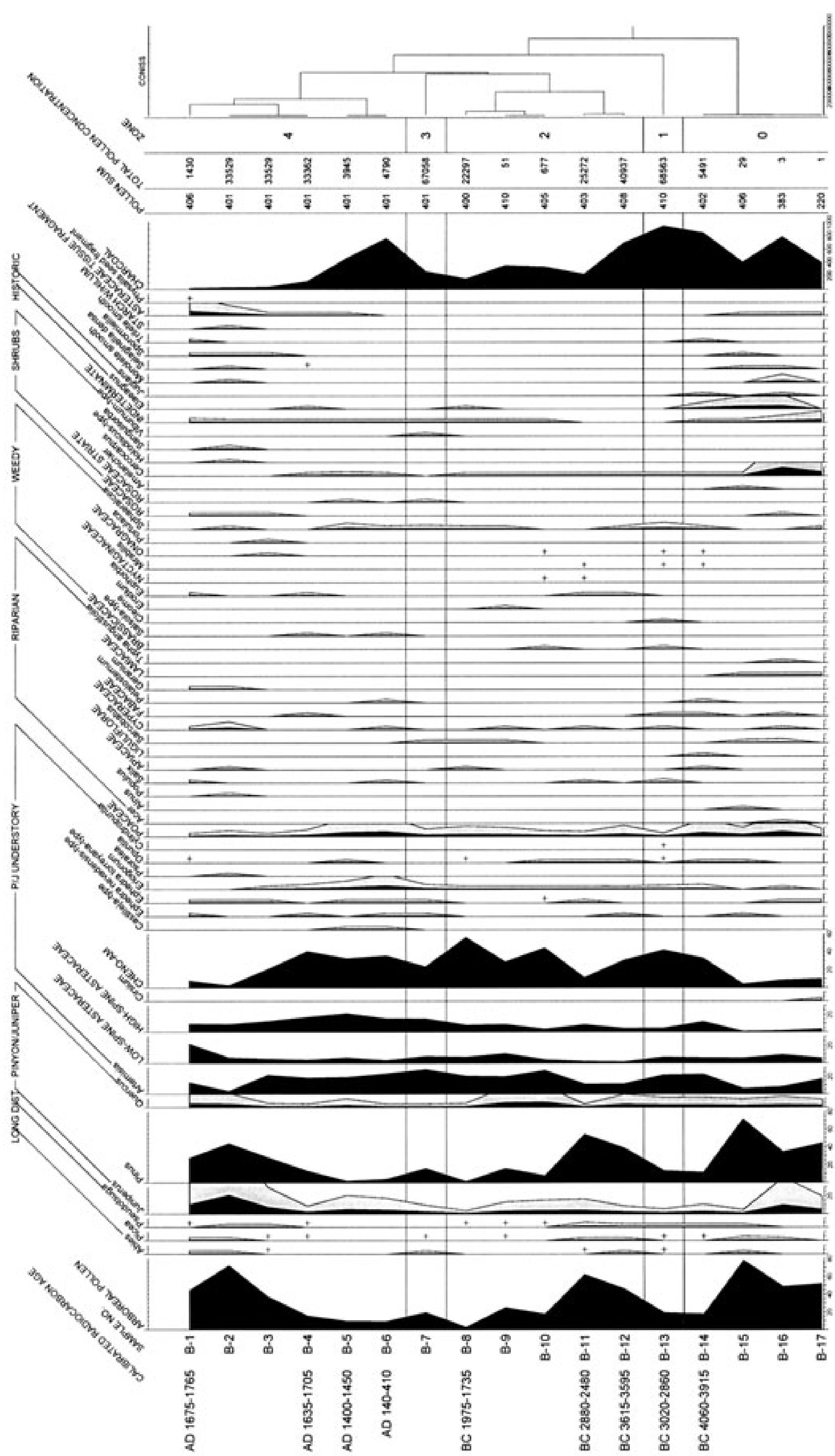

Figure 3. Section B pollen percent diagram, charcoal shown as particle counts.

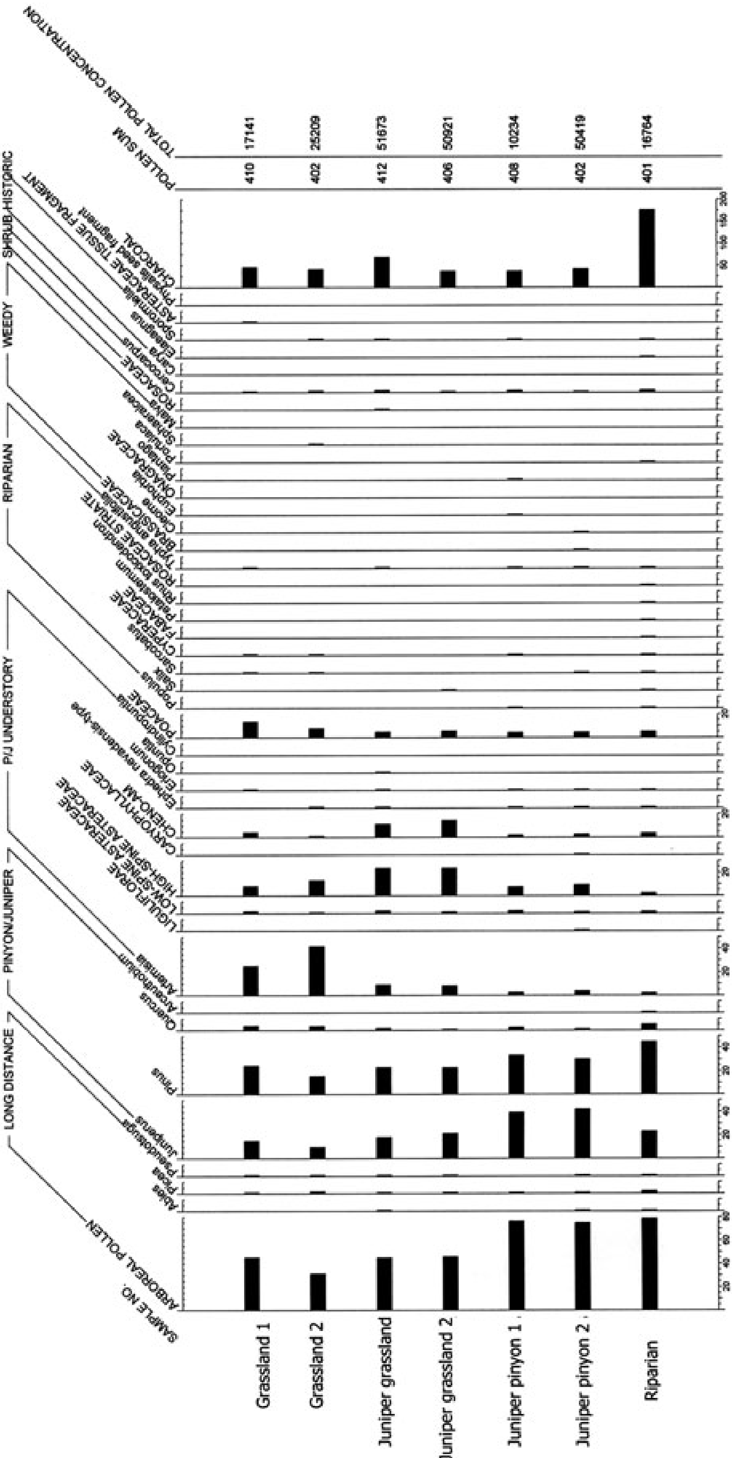

Figure 4. Pollen percent diagram, surface samples, charcoal shown as particle counts.

RIO DEL OSO PALEO-LANDSCAPE

Archaeological evidence of the early Archaic period (ca. 5500 B.C.–A.D. 600) in the Rio del Oso Valley is scarce on the modern surface. Archaic-period material can be found in the arroyos and tributary drainages bordering the main river channel. Hearths, lithic scatters, and ground-stone artifacts characterize such sites. Exposed Archaic sites provide a chronicle of the geological forces responsible for their burial and the past configuration of the long-concealed landscape. The total area of Archaic sites is approximately 30 ha, distributed among 128 sites, and many of these contain components of Puebloan-period occupations, showing a continuity of place usage. Campsites and stone-tool manufacturing areas make up most of the Archaic period sites.

Palaeobotanical analyses of the Rio del Oso's past vegetation communities revealed that, although oak was more common than it is today, there appears to have been little differentiation between the species identified in current surface plots. This landscape was dominated by grassland, and juniper, ranging from approximately one tree-per-hectare to two trees-per-hectare, while the per-hectare density of pine in the lower drainage was lower. Juniper and pine pollen preserved in the fossil record likely represents an influx of particles from higher-elevation woodland. Oak pollen in the fossil record far exceeds current levels in the lower portions of the drainage, while no mature oak trees were present in the surface-vegetation sample plots. Although R-values were not calculated due to the lack of current oak samples, the consistent prevalence of oak in the fossil pollen record enabled estimates of oak density in visual models of past Rio del Oso landscapes (Figure 5).

Vegetation change during the Archaic period occurred as fluctuating frequencies of specific taxa, and fires were common. The high occurrence of late Archaic microscopic charcoal (10–25 μm particles) suggests burning of grassland on a landscape scale. These smaller particles represent tiny airborne particles from landscape-level fires, while larger microscopic charcoal particles suggest localized fires (Clark and Royall, 1996; Delcourt and Delcourt, 1996).

During the Puebloan-period occupation of the valley (ca. A.D. 1300–1600), agriculture went from being a supplemental to a dominant food source. The Rio del Oso floodplain was at least 5–8 m higher than current levels, and the frequency of recorded Puebloan archaeological sites in the lower valley is the highest of any period (237 sites in approximately 196 ha). The fossil pollen and phytolith record shows high levels of disturbance-related vegetation, and sedimentation rates increased to 14+ cm per century. In Section A, this increase in floodplain aggradation represents a near-doubling of the sedimentation rate, from a mean rate of 7.65 cm per century. In the upper portion of Section B, from approximately A.D. 1400–1765, the sedimentation rate increased to 16.42 cm per century.

The influence of fire in the Rio del Oso landscape appears to have diminished between approximately A.D. 400 and 1600, counter to paleoenvironmental studies in which large-scale increases in microscopic charcoal suggest human presence and environmental manipulation (Caseldine and Hatton, 1993). Paleobotanical evidence in the Rio del Oso landscape indicates that it was dominated by grassland with scat-

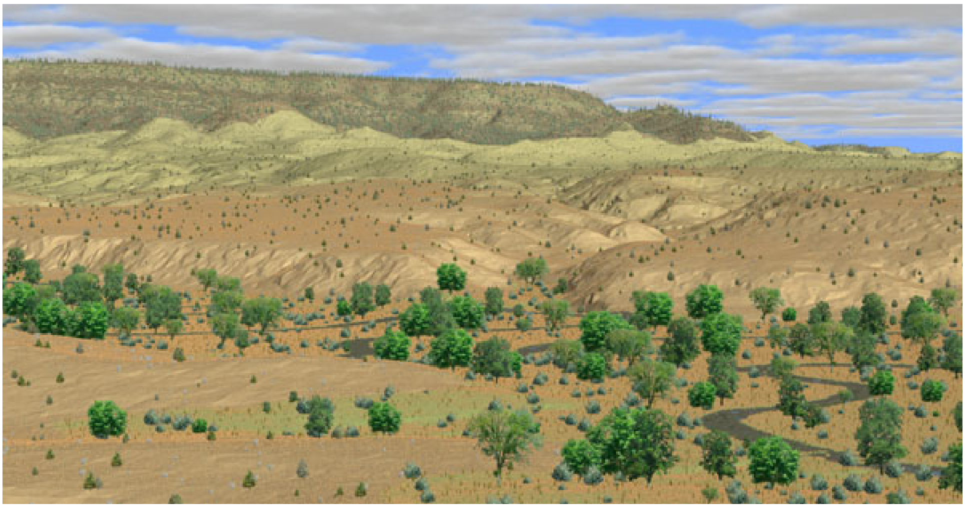

Figure 5. Model of the Rio del Oso's Archaic period (1000 B.C.) vegetation patterns. This landscape was dominated by grassland with oak. Juniper ranged from approximately 1 tree per hectare to 2 trees per hectare, while the per-hectare density of pine in the lower drainage was lower. The sedimentation rate ranged from 5 cm per century to 8 cm per century.

tered juniper rather than woodland before significant impact by horticulturalists. Pine and juniper density were within the same range as during the Archaic period. The Puebloan landscape consisted of open grasslands, dominated visually by a central village, with fields dispersed across the floodplain, and supplementary agricultural features on Pleistocene terraces. The population of surrounding areas and centralized villages, as well as the creation of fields and frequently used trails, exposed soil to wind and water erosion and likely resulted in greater sedimentation on the valley floor.

The Spanish-period landscape (A.D. 1700–1846) differed greatly from its predecessors. Forty-six archaeological sites recorded from this period cover an area of 63 ha. Colonial documents from the 18th century reveal that by the 1730s, Spanish settlers lived in the upper portion of the Rio del Oso canyon (Wozniak et al., 1992). These communities imposed an Old World model of land use on the Rio del Oso landscape. Colonists depended on subsistence farming, and introduced ranching and livestock, including horses, cattle, sheep, and goats. The Spanish-period landscape consisted of rectangular fields with straight lines of construction, grazing herds of large, domestic ungulates, and encroaching juniper. This created a composite landscape built upon the ruins of Pueblo land-use systems.

In the lower Rio del Oso Valley, Spanish-period juniper density increased to 10+ trees per hectare, while disturbance vegetation, once used by Puebloan peoples, declined to the lowest levels observed during the past 6000 years, and fire levels fell sharply (Figure 6). Alluvial aggradation decreased in the lower portion of the valley, and terminated after A.D. 1765. The valley floor had been stable, with steady sedi-

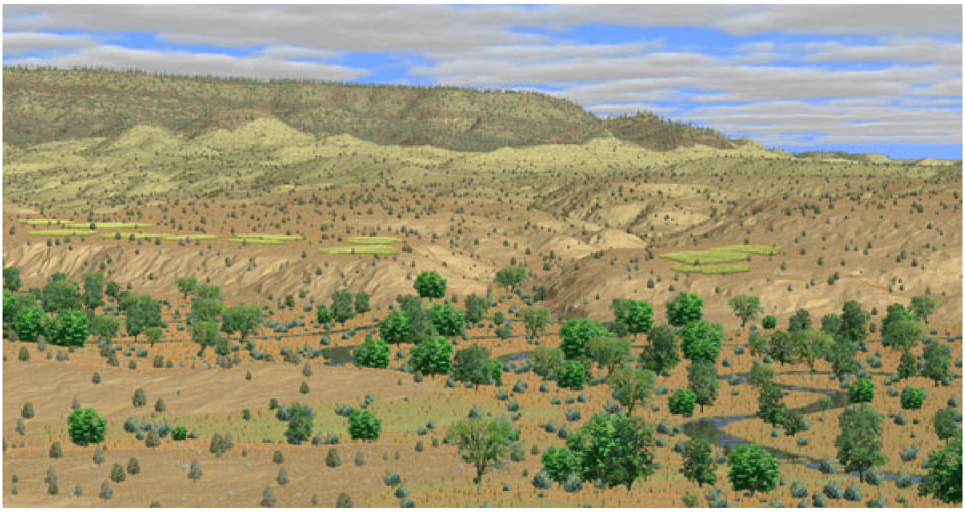

Figure 6. Model of Rio del Oso vegetation patterns at the end of the Puebloan period (A.D. 1500). Settlement and sedimentation increased to as high as 16 cm per century by the time the pueblos were abandoned and tree densities were at approximately 4 trees per hectare. Puebloan agricultural features are modeled as light-colored polygons in mid-ground. Massive erosion began with the introduction of Spanish livestock and village development in the valley. By 1750, juniper densities were already at more than 10 trees-per-hectare.

ment accumulation during the previous 7000 years; however, Spanish-period erosion dramatically altered the Rio del Oso ecosystem. With the arrival of Spanish livestock in the 17th century, down-cutting of the floodplain likely began. What had been a rich, meandering stream and riparian area became a hydrological system of braided channels, characterized by a network of constantly shifting, low-sinuosity courses. Such systems are characterized by a network of channels without clearly defined overbank deposition. This is evident in the laminated, cross-laminated, and desiccation-cracked fine sands and silts from the lower strata of Sections B and C. The remnants of the former floodplain are now arid, supporting mostly juniper and cholla.

There is a lack of data documenting ecosystem change in the Rio del Oso landscape after the Mexican American War of 1846–1848. Historic paleobotanical records of Southwestern landscapes primarily consist of information from early expeditions of the U.S. Army. Gaps in this vegetation history may be filled by research of sediments from relict paleochannels, peat bogs, or other sources. Although sedimentation increased in the Rio del Oso Valley before Spanish settlement, this aggradation was followed by erosion and the expansion of the New Mexican cattle industry in the 1870s. Overgrazing caused massive decreases in vegetation cover, plant vigor, and the suppression of natural fires. The Rio del Oso landscape had already been exposed and eroded by the time of the 1890s Southwestern drought, and vulnerability to the forces of wind and water erosion only increased. Reduced upland and valley plant cover led to an estimated loss of at least 6 inches of vital topsoil (Wildeman and

Figure 7. Today the Rio del Oso landscape exhibits juniper densities of <80 trees per hectare, while pine is now near 15 trees per hectare. Most of the alluvium accumulated before 1750 has been removed by broad-scale erosion to a depth 6–8 m below the A.D. 1500 surface, and Pleistocene gravels lay exposed in a braided stream channel.

Brock, 2000:19–22). The floodplain, stripped of vegetation by grazing, became a labyrinth of arroyos when seasonal rains returned. Presently, the Rio del Oso landscape has juniper densities of >50 trees per hectare and pine densities of 15 trees per hectare (Figure 7). Many watersheds affected by this 1890s ecological crash have never recovered (Wildeman and Brock, 2000:19–22).

CONCLUSIONS

This Rio del Oso landscape history incorporated interdisciplinary environmental sciences vital to ecological analyses, including paleoenvironmental data, geoarchaeology, paleoecology, and spatial modelling. Geomorphological and paleobotanical analyses of the sedimentary processes, vegetational composition, and structure of past landscapes, provided further insight into the role of humans in the creation of that structure. Various cultures inhabited the Rio del Oso, affecting landscape through the use of applied fire, plant manipulation, agriculture, transportation, and shelter construction. The Rio del Oso was imprinted by hunter-gatherers, Pueblo settlements, and forces of the world economic system with European colonization. Archaeological information was instrumental in providing direct spatial and temporal understanding of human influences on the evolution of the Rio del Oso landscape. The nature and extent of anthropogenic landscape change during the past 7000 years in the Rio del Oso Valley may reveal how past human activities continue to influence ecosystem characteristics, and provides perspective regarding present and future environmental conditions.

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