Archaeological Geology of the Mescalero Sands, Southeastern New Mexico

Stephen A. Hall and Ronald J. Goble

The Mescalero Sands accumulated in two episodes, first during the late Pleistocene (90,000 to 75,000 years B.P.) and second during the early Holocene (9000 to 5000 years B.P.) based on OSL dates. Archaeological sites of all ages occur on the surface of the older eolian sand. Sites later than 3000 B.C. occur on the surface of the younger eolian sand, and sites older than 3000 B.C. are buried within the younger sand unit. Historic coppice and parabolic dunes partly cover all prehistoric sites. Paleoindian sites may be associated with late Pleistocene spring and cienega deposits and buried by the younger eolian sand. Sediments at sites within the younger eolian sand unit are bioturbated by cicada insects. Burned caliche at archaeological sites is dominated by dense pisolitic Caprock calcrete from the top of the Ogallala Formation. Cobble-size clasts of Caprock calcrete and other lithologies are prehistoric resources that occur in terrace and lag gravel colluvial deposits west of the escarpment. An archaeological geologic map of about 1,295 square kilometers of Eddy and Lea counties shows the distribution of areas where sites are visible at the surface as well as areas where sites are potentially buried in young deposits.

Keywords: New Mexico archaeology, eolian geomorphology, OSL, geoarchaeology, archaeological geologic map

The landscape at any instant of geologic time is characterized by only one of three conditions: deposition, erosion, or stability; the scale of geologic time is century to millennium. The three conditions dictate the visibility and integrity of archaeological sites. Each of the three landscape states has dominated the Mescalero Sands at one time or another during the past 20,000 years, and, consequently, the preserved archaeological record is a reflection of these changing conditions.

STRATIGRAPHY AND GEOCHRONOLOGY

The Mescalero Sands is a large sand sheet with stabilized dunes extending north and south in a 32 to 48 km wide band west of the Caprock escarpment of the High Plains at the transition of the southwest Great Plains and the northeast edge of the Chihuahuan Desert. The eolian sand thins in the north in the vicinity of Clovis, New Mexico, and in the south the Mescalero Sands merge with the Monahans Sandhills of west Texas. The surface of the sand sheet is characterized by parabolic dunes in the center and coppice dunes along the margins. Both parabolic and coppice dunes are historic in age. A few small patches of active transverse dunes occur in the midst of broader areas of predominantly stable parabolic dunes (Hall and Goble 2006; Mahoney 2003). The sand that makes up the Mescalero Sands is probably derived from the Ogallala Formation and not from Pecos River alluvium (Bachman 1976; Muhs and Holliday 2001).

The Mescalero sand sheet is formed by two

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layers of eolian sand of different ages that mantle the eroded top of the Mescalero paleosol. The Quaternary geology and OSL geochronology of the sand sheet have been described in detail elsewhere (Hall 2002a, 2002b; Hall and Goble 2006) and are briefly summarized below (Figure 1).

Optically Stimulated Luminescence (OSL)

OSL provides a method of determining the burial age of sand grains, and therefore the time of deposition of eolian sand deposits. Natural ionizing radiation produced by the decay of radioactive materials present in all sediments produces electrons which become trapped at positive defects in the crystal structure of sand grains. Upon exposure of the sand grains to light, either sunlight or an artificial light source, these electrons are released. A portion of the electrons are then re-trapped at other, lower energy crystal sites, resulting in the emission of light from the sample. The intensity of light emitted is a function of burial time, or the OSL age, and the concentration of radioactive elements (Aitken 1998; Goble et al. 2004).

OSL can be applied to almost any sand-bearing sediment that has not been disturbed, including eolian sand and alluvium. OSL ages can be obtained routinely from deposits ca. 200,000 to 50 years old. OSL ages are in calendar years.

Mescalero Paleosol

The Mescalero paleosol is a calcic soil that formed prior to 100,000 years ago on the eroded surface of Permian and Triassic rocks as well as locally on some Pleistocene deposits. The paleosol underlies the sand sheet and is about 1 m thick with stage II to III carbonate morphology. The top of the paleosol is eroded at most localities with only the Bk calcic horizon present, the upper part of the B horizon missing. While the calcic paleosol is resistant to erosion and locally forms low escarpments, the degree of carbonate cementation is weak and crumbles by hand and is not sufficiently dense to have been used as hearth stones at archaeological sites.

Lower Eolian Sand and Berino Paleosol

Directly on top of the eroded Mescalero paleosol is reddish eolian sand generally no more than 0.5 m thick but ranging up to 3 m thickness at a few places. One of the thicker sections is dated 87,400 ± 4500 and 81,700 ± 3600 years old by OSL with the age of the Lower eolian sand unit extrapolated to about 90,000 to 75,000 years B.P.

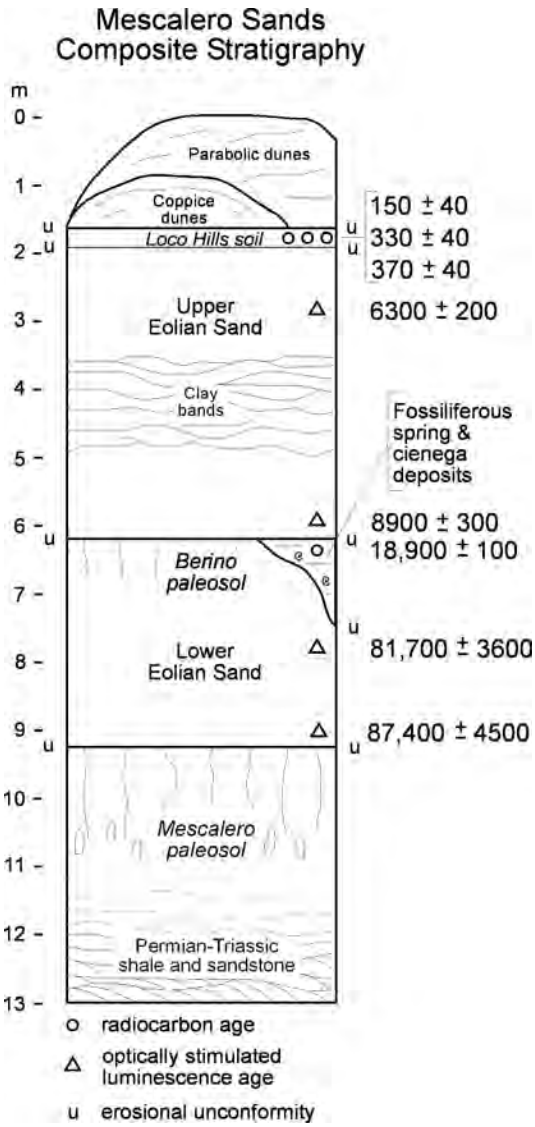

Figure 1. Composite stratigraphy and age of the Mescalero Sands, southeastern New Mexico; no single exposure incorporates all stratigraphic units together.

The eolian deposition of the Lower sand occurred over a wide region including beyond the specific area of the Mescalero Sands. The Lower sand was exposed to weathering throughout the time span of the Wisconsin Glaciation during which the climate was comparatively cool and moist and the vegetation was sagebrush grassland, at least during the later Wisconsinan (Hall 2005). Consequently, soil development on the Lower sand produced an argillic, noncalcic soil called the Berino paleosol (Bachman 1984; Hall and Goble 2006). The argillic paleosol is characterized by a distinctive red color and a general hardness to the upper part of the Lower sand, distinguishing it from the younger Upper eolian sand that is yellow and soft.

Broad areas along the western and eastern margin of the sand sheet are characterized by coppice dunes that have formed around individuals of Torrey mesquite (*Prosopis glandulosa torreyana*). Torrey mesquite evidently thrives on the exposed surface of the Lower eolian sand because it is abundant there and uncommon in areas underlain by the Upper eolian sand.

Upper Eolian Sand

The Upper eolian sand is the main component of the Mescalero Sands. It is generally 4 to 5 m thick in the core of the sand sheet and is partly stabilized by shinnery oak (*Quercus havardii*), a low-growing shrubby plant that reproduces vegetatively and is endemic to sandy soils in the southwest Great Plains (Peterson and Boyd 1998). The Upper sand is dated 8900 ± 300 and 6300 ± 200 years by OSL. The age of the Upper eolian sand unit is extrapolated to about 9000 to 5000 years B.P. The broad cover afforded by shinnery oak vegetation promotes the development of parabolic dunes on the surface of the Upper sand.

Loco Hills Soil

The Loco Hills soil is an A horizon soil that occurs at the top of the Lower and Upper eolian sand, in alluvium, and on colluvial surfaces throughout the region. It is young with ages ranging from 370 to 150 ^{14}C yrs B.P. (data in Hall 2002a; Hall and Goble 2006). The soil likely formed on a stable surface of desert grass vegetation. The grass cover captured eolian sand resulting in a buildup of 10 to 20 cm of fine sand deposits during the period of stability in the last few centuries. The soil does not have a B horizon. The Loco Hills soil is developed over the sediments that incorporate archaeological sites but is not related to prehistoric occupations; it should not be confused with anthrosols that form concurrent with site habitation.

ARCHAEOLOGICAL GEOLOGIC MAP

The archaeological geologic map is a new category of map that depicts the surficial geology and its relationship to the exposure or burial of archaeological sites of different ages (Figure 2). Built into map categories is site preservation that generally reflects the degree of alteration that occurs to sites after they are abandoned, whether the site is in alluvium, in eolian sand, or on a colluvial surface. Rock shelter and cave sites are special circumstances not dealt with here.

The archaeological geologic map of the Mescalero Sands covers about 1,295 square kilometers of northeast Eddy and northwest Lea counties, southeastern New Mexico, and was prepared from black-and-white stereo aerial photographs (scale about 1:52,000) and color infrared stereo aerial photographs (scale about 1:86,000) that were obtained from the EROS Data Center, Sioux Falls, South Dakota. The field area was investigated and mapped in 2000, 2001, and 2003. The archaeological geologic map was initially prepared on USGS topographic maps (scale 1:24,000) that serve as base maps on which landforms and landscape features are drawn. Features smaller than about 200 feet across were not mapped. Three units dominate the map: Coppice dunes on the Lower eolian sand (Qc), Parabolic dunes on the Upper eolian sand (Qp), and Denuded surfaces (Qd), together comprising 98 percent of the mapped area (Table 1).

An archaeological geologic map can be prepared for any geographic region where the Quaternary geology and geomorphology are known. The preparation of an archaeological map requires a firm understanding of the surficial geology, the age of the surficial deposits and soils, the field appearance of archaeological sites, and a sense of how these entities are related in the landscape. A practical map scale is that of USGS 7.5 minute quadrangles (1:24,000) on which geomorphic map units and archaeological sites can be plotted together. Needless to say, an archaeological geologic map is of immense value in cultural resource

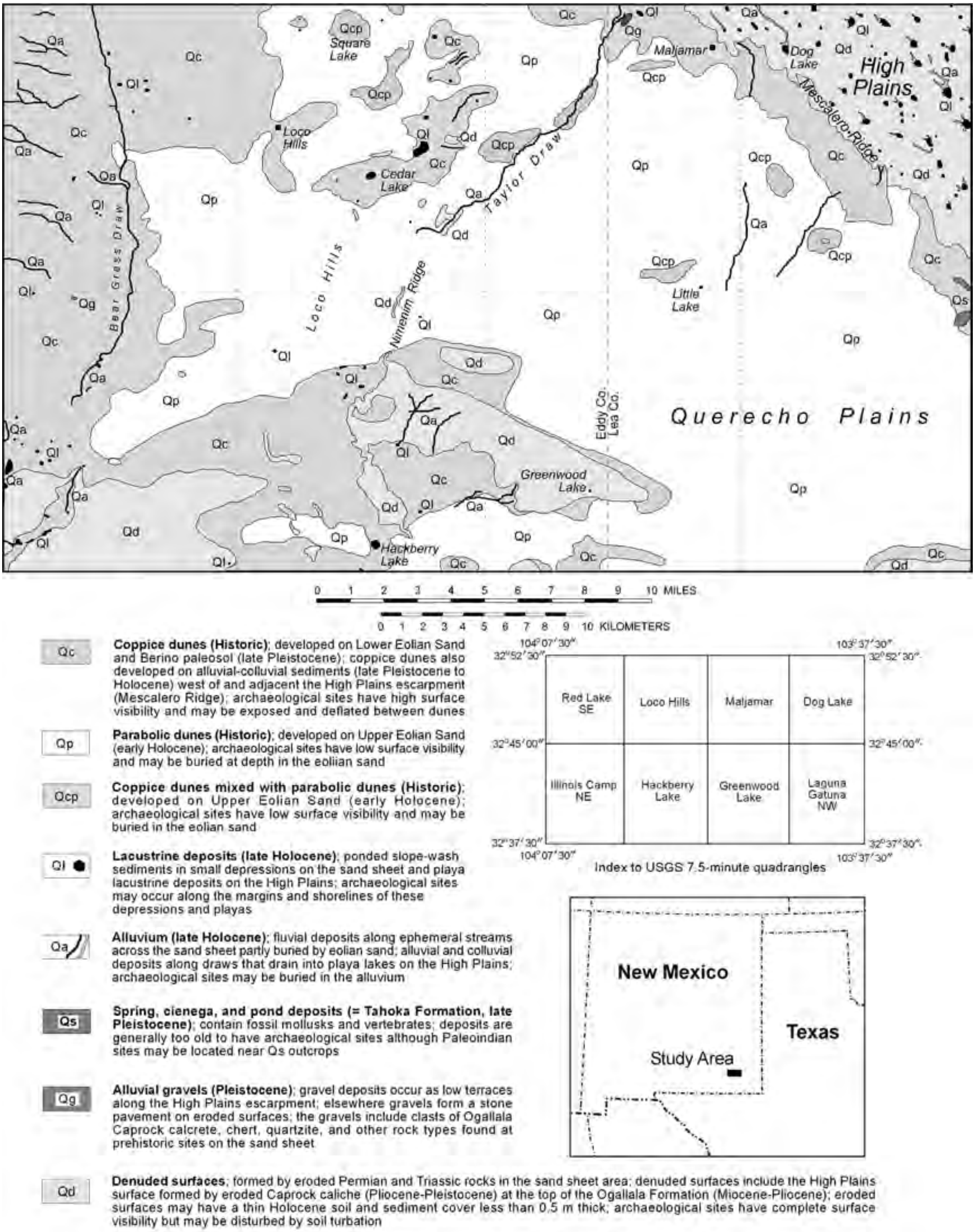

Figure 2. Archaeological geologic map of the Mescalero Sands area, Eddy and Lea counties, southeastern New Mexico; mapped by Hall in 2001, 2002, and 2004.

Table 1. Map Units from Archaeological Geologic Map of the Mescalero Sands, Southeast New Mexico.

Map Symbol	Description	Area (%)	Site Status
Qc	Coppice dunes on Lower sand	31.0	Sites of all ages occur on surface & beneath historic coppice dunes
Qp	Parabolic dunes on Upper sand	54.7	All sites occur beneath historic parabolic dunes; sites <3000 BC occur on surface; sites >3000 BC are buried in Upper sand unit
Qd	Denuded surfaces	13.0	Sites of all ages occur on eroded surfaces
Qa	Alluvium	0.7	Sites of all ages are buried in alluvium

management, although no map is a substitute for field observation.

ARCHAEOLOGICAL GEOLOGY

Archaeological Sites and the Sand Sheet

The distribution and age of the two sand layers that make up the Mescalero sand sheet have a direct bearing on the visibility, hence distribution, of known archaeological sites (Figure 3). The Lower eolian sand unit is late Pleistocene in age, and sites of all ages occur on its eroded surface and have high visibility, although sites may be partly buried and obscured by mesquite coppice dunes. The Upper eolian sand unit is early Holocene in age, and sites older than 3000 B.C. occur buried within the thick sand and are not visible at the surface. The Upper sand may also cover Paleoindian sites. Because eolian accumulation of the Upper sand ended about 5000 years ago, archaeological sites younger than 3000 B.C. occur at the sand's surface and have moderate visibility, depending on the degree of parabolic dune development (Figure 4).

During the past 5000 years, the sand sheet has been in a state of quasi-stability with no new sand being deposited and no old sand lost by deflation. The surface of the sand sheet was subject to periodic sand movement, with localized deflation and deposition, perhaps due to dual wind directions such as observed in the Monahans Sandhills of west Texas by Machenberg (1984). Plant cover may have been predominantly shinnery oak. Regardless the situation, the surface was not sufficiently stable for soil development to have occurred.

Archaeological sites younger than 3000 B.C. that are on the surface of the sand sheet may have a 10 to 30 cm cover of recent eolian sand, the result of localized sand deflation and deposition since the site was abandoned. After about A.D. 1500, however, the sand sheet became stabilized by desert grasses and the Loco Hills soil formed. The Loco Hills soil is much younger than and overlies most of the sites with which it may be associated.

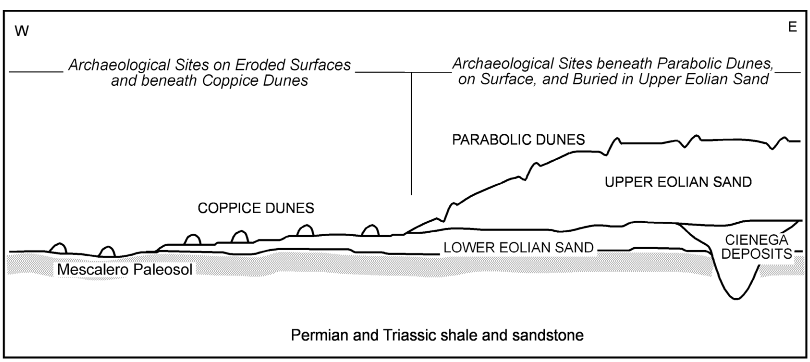

Figure 3. Distribution of archaeological sites related to surficial geology across the Mescalero Sands, southeastern New Mexico.

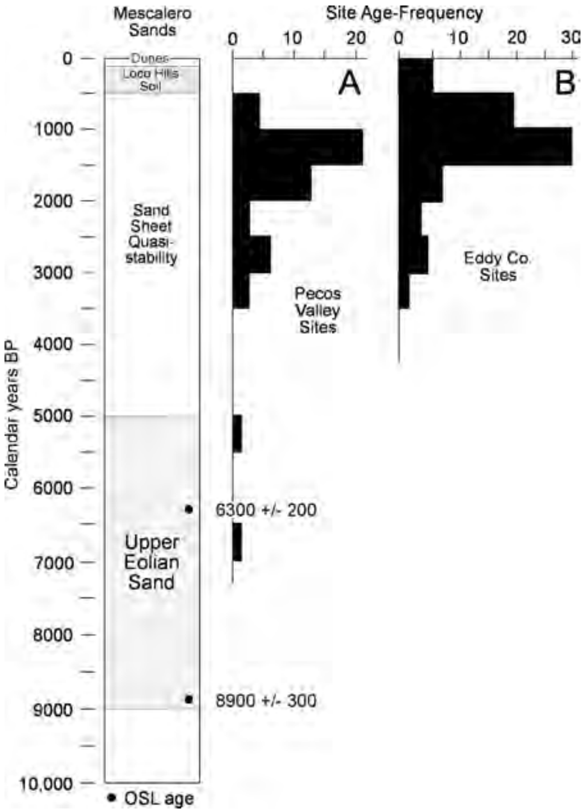

Figure 4. Frequency of radiocarbon dates from archaeological sites in (A) the Pecos Valley region of the Roswell District (Sebastian 1989), and (B) Eddy Co. (Katz and Katz 2000, excluding sites listed in Sebastian 1989); radiocarbon dates are converted to calendar years (Calib 4.1 program, Stuiver and Reimer 1993; Stuiver et al. 1998).

Sites in Coppice Dunes and on Lower Eolian Sand Unit

Archaeological sites are common and well exposed in the area of mesquite coppice dunes due to recent erosion between dunes and erosion of the dunes themselves. The sequence of geomorphic events leading to the present-day high visibility of sites in areas of coppice dunes is straight-forward: (1) erosion of the Lower eolian sand during the late Pleistocene, (2) formation of archaeological sites on the eroded surface during the Holocene, (3) continued deflation of the Lower eolian sand as well as the deflation of archaeological sites and features on the old surface of the Lower sand, (4) stability of the deflated surface after ca. A.D. 1500 and the establishment of a dense cover of desert grasses, (5) accumulation of 10–20 cm of fine eolian sand that is trapped by the grasses, and (6) development of the Loco Hills soil A horizon. At this stage, previously eroded archaeological sites are mantled and somewhat protected by the thin cover of the Loco Hills soil that post-dates the sites (Figure 5).

All of this changed with the arrival of American settlers and their cattle. By the turn of the century, local overgrazing by cattle led to the decline in desert grasses and the spread and increase in abundance of Torrey mesquite. Wherever mesquite shrubs germinated, coppice dunes developed within a few years. In the Mescalero Sands area, mesquite coppice dunes probably formed mostly ca. 100–120 years ago on the then-deflating surface that contained the Loco Hills soil. In areas where the mesquite first invaded, remnants of the Loco Hills soil may occur beneath the coppice dunes. In other places where dunes formed later in the early twentieth century, the Loco Hills soil is entirely gone, the sand matrix of the soil deflated and redeposited in adjacent dunes.

Within the past 50 years, the erosion of mesquite coppice dunes in some areas has removed as much as 40 cm of sand from below the pre-dune surface (marked by the Loco Hills soil) (Figure 6). In these cases, archaeological sites and associated features are obliterated, and artifacts and burned rock form a pavement of lag gravels on the eroded surface. Sheet run off from rainstorms further moves artifacts and materials from their initial position at sites. In other areas where recent erosion is less severe, features that intrude the Lower sand unit may be intact and concentrations of artifacts may still be close to their initial position within site boundaries. In all cases, however, sites on the Lower sand unit do not seem to have a sediment matrix and occur on the old eroded surface of the red sand with features intruding into it (Figure 7).

Sites in Parabolic Dunes and Upper Eolian Sand Unit

Archaeological sites are poorly exposed in areas of parabolic dunes. Low site density in these areas is related at least in part to low site visibility. Other factors that affect site density, ranging from survey-density data to prehistoric cultural preferences, are beyond the scope of this paper (Sebastian et al. 2005).

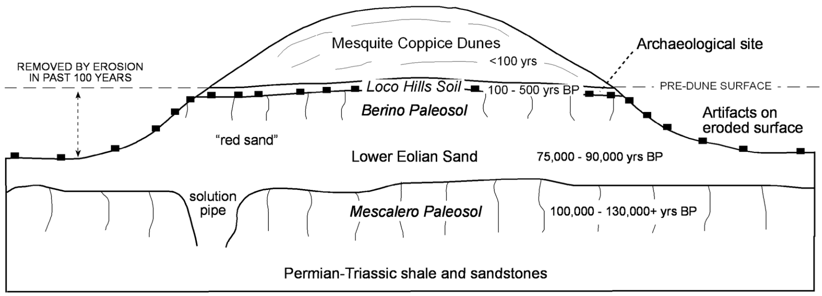

Figure 5. Position of archaeological sites in area of Lower eolian sand and mesquite coppice dunes; field observations show that most if not all sites have been deflated prior to the accumulation of the coppice dunes; areas between dunes are further eroded in historic time since the formation of the coppice dunes.

Parabolic dunes are U-shaped dunes with the tips of the dune tapering windward. The dunes are formed on the downwind side of small blowouts that are deflated in the comparatively thick Upper sand unit. Sand from the blowouts predominantly forms the parabolic dunes. This dune type has been described as "parabolic dunes of deflation" by Hack (1941:243).

Archaeological sites are exposed in the bowl-shaped blowouts immediately windward of the parabolic dunes. The most common archaeological remains visible in blowouts are large fire-cracked rocks. However, in many cases, the blowout itself is partly buried by 10 cm or more of recent loose sand that may completely mask the presence of a site. Field experience has shown that loose sand comes and goes. Site materials may be exposed in a blowout at one time but made invisible by loose sand at another, posing a serious field problem for site surveys.

Figure 6. Eroded surface of the Lower eolian sand around mesquite coppice dunes; both large and small pebbles are derived from deflated surface mounds of ant colonies and from deflated material dug up by burrowing rodents and carnivores; at archaeological sites, burned calcrete and artifacts are mixed and deflated along with the pebbles.

Potential Presence of Sites beneath Dunes

Eroded mesquite coppice dunes in the Mescalero Sands are often surrounded by deflated surfaces strewn with artifacts, and it seems intuitive to expect that intact archaeology is preserved beneath the dunes. However, sites on the surface of the Lower sand have been previously eroded before the historic dunes formed. Thus, even though a few artifacts may occur beneath a coppice dune, intact archaeology is most likely absent, having eroded before the coppice dune formed.

Parabolic dunes in the Mescalero Sands are a

Figure 7. Caprock calcrete-lined hearth that intrudes Lower eolian sand unit; while the undated feature may be a couple of thousands of years old, the sand in which it was dug is 75,000 years old; the prehistoric surface at the time the site was inhabited has been removed by post-site erosion; only the lower part of the calcrete-lined hearth remains; recent sand drifts around the feature.

different situation concerning site visibility from the nearby coppice dunes. Parabolic dunes all have blowouts on their windward side, some exposing previously buried archeological sites. However, the blowouts are partly vegetated and hold sand that is deposited after the blowout was eroded.

Sites on Denuded Surfaces

Denuded surfaces are generally formed by long-term erosion of old rocks or deposits that predate the local archaeological record. In the Mescalero Sands, denuded surfaces occur on Permian, Triassic, and Cenozoic rocks. Today, many of these surfaces are mantled by a thin cover of weathered rock and eolian silt, mixed together in a colluvial deposit as much as 30 or 40 cm thick. Archaeological sites of all ages, from Paleoindian to historic, occur on these surfaces. The sites themselves are severely turbated by burrowing animals, and only the largest features may be intact. In the area shown in the archaeological geologic map, 13 percent is denuded surface (Table 1). Sites in these areas have 100 percent surface visibility. Even if a site that formed on a denuded surface is buried by several centimeters of eolian silt, bioturbation and patchy erosion will expose artifacts at the present-day surface, and site surveys should be able to record its presence.

The eroded surface of the Lower eolian sand is also denuded although the presence of mesquite coppice dunes introduces another element of surficial geology that in some cases may mask archaeological sites.

Early Sites and Pleistocene Cienega Deposits

During the Late Wisconsinan glacial age, approximately 35,000 to 14,000 years ago, the region experienced greater amounts of both surface water and ground water. Streams were larger, carrying gravels, and the regional water table was higher, promoting large springs and spring-fed cienegas. This is especially true for the Ogallala aquifer that fed large cienega streams flowing westward from the Caprock escarpment. The deposits in a former cienega north of Maljamar community are 5 m thick and 1.6 km wide (locality 11, SW1/4, SW1/4, Sec. 3, T16S, R31E in Hall 2002a; Hall and Goble 2006). Fossil mammals and snails occur in these deposits, the mollusks indicating wetter and cooler conditions than present (Ashbaugh and Metcalf 1986). Aragonitic shells at one place were AMS radiocarbon dated 18,900 ± 100 ^{14}C yrs B.P. (Beta-156514; $\delta^{13}C$ = -7.7) (locality 14 in Hall 2002a). These deposits correlate with the Tahoka Formation on the High Plains of New Mexico and Texas (Hall 2001).

The geographic extent of the cienegas is not well known. Many cienega deposits are buried by the Upper eolian sand and are exposed only in blowouts within the Mescalero sand sheet. The potential for discovering Paleoindian sites beneath the Upper sand unit and adjacent late Pleistocene cienega deposits seems high.

SITE DISTURBANCE

Carnivores, Rodents, Ants, and Cicadas

Burrowing animals dislocate the mineral grains that make up the natural stratigraphy of sediments and soils. The position of cultural materials in archaeological sites is also altered. Field observation shows that large animals, especially carnivores such as coyotes and badgers, cause greater disturbances than do small animals. Badgers are probably the most destructive burrowers, digging ferociously after their average diet of 1.7 rodents per day (Findley 1987). Badgers even dig through stage III calcic soils, following their prey, and can produce a meter thick zone or biomantle of surficial sediment in which materials from archaeological sites and sediments are completely churned (Johnson 1997). The degree of mixing is so thorough and pervasive that it may be overlooked in archaeological excavations.

Rodent burrows are more conspicuous, their round tube-like burrows winding through soft sediments. The outlines of their burrows are obvious features in the vertical walls of archaeological excavations, their presence often marked by a different color of fill than that of the excavation walls. Artifacts, charcoal, and site sediments that are included in these burrow fills can be taken into account in the field and avoided.

More insidious burrowers are cicada insect nymphs that live underground, feeding on juices from rootlets for 13 or 17 years before their cyclic emergence as adults for only 4 to 6 weeks. Cicadas produce small burrows, generally 10 to 16 mm diameter. They excavate by pushing the sediment back into the passage through which they have passed, leaving behind crescent-ridged burrow fills (Figure 8). Because the sediment in the burrow fills is generally the same sediment through which they dig, the burrow fills are often indistinguishable from adjacent undisturbed sediment.

Field observations have shown that, when archaeological trenches or excavations are left open for one to two weeks, sand abrasion of the dry trench walls produces a faint relief in which the burrow fills are revealed. In some cases burrows cross other burrows and the sandy sediment is 100 percent turbated by cicada insects.

The presence of large rock features in buried sites, such as rock-lined hearths, is often pointed out as evidence that the site stratigraphy is intact. While badgers might make swift work of scattering rock features, cicada insect nymphs burrow around each stone without disturbing them, leaving them in place. In such a case, the rock feature survives virtually intact, but the sediment surrounding the stones may be completely churned up over time. The churning of the sediment at an archaeological site will greatly affect the stratigraphic position of small artifacts, bones, shells, seeds, as well as the sediment collected for textural, chemistry, isotope, and pollen analysis.

Ant colonies cause minimal disturbance to the sediments in archaeological sites. However, they bring to the surface large amounts of small pebbles from subsurface deposits. In a study at the Mescalero Sands, ants bring to the surface 84 grams of material per square meter of area in one year (Whitford et al. 1986). If uniform, this can be extrapolated to 37 tons per acre per century. Regarding the burrowing activity of mammals and insects in the area, it is little wonder that present-day deflated archaeological sites are paved with a mix of artifacts and numerous non-cultural pebbles.

Sediment Disturbance and OSL Ages

Burial ages determined by OSL dating can be affected by burrowing in two ways. First, if the burrower brings the material completely to the

Figure 8. Cicada insect burrow fills exposed in a blowout in Upper eolian sand at a depth of about 5.5 m; the burrows are visible in micro-relief on the vertical face due to sand abrasion and differential hardness of the individual burrows and surrounding sand; upon scrapping with a trowel, the visibility of the burrows disappears; vertical surfaces require one week or more of exposure and abrasion before subtle features are revealed.

surface, the OSL signal will be reset to zero. Second, if burrowing mixes sands of different ages, the OSL signal will give rise to an intermediate age. The latter is resolvable using single-grain OSL dating or, possibly, with the use of smaller aliquot sizes. Depending upon sedimentation rates, fine-scale disturbance such as by cicada insects may be within the 1-sigma range of the OSL age. Each case is distinct, however, and the degree of disturbance must be taken into account when a sediment column is sampled for OSL dating.

BURNED CAPROCK CALCRETE

Sites in the Mescalero Sands area and throughout the region are characterized by the presence of numerous pieces of burned calcrete, also known as fire-cracked rock. Not every lithology is suitable for use in hearths. Inspection of large numbers of burned stones shows that, of the many rock types available for selection, most of the burned rocks are rounded cobbles of densely-cemented calcrete from the Caprock of the Ogallala Formation that outcrops east of the Mescalero sand sheet.

The Caprock calcrete throughout the High Plains is commonly a stage V level of carbonate morphology with some stage IV and more rarely stage VI calcrete (see Birkeland 1999:357 for a summary of stages of carbonate morphology; see Gustavson 1996 for a recent summary of the Ogallala Caprock). Stage V and VI calcrete occurs along the present-day western edge of the Caprock with a morphology characterized by dense, entirely-cemented carbonate variously with massive, laminar, pisolitic, or brecciated features (Figure 9). Rounded cobbles of calcrete are found in gravels and on colluvial slopes west of the Caprock escarpment. The gravels and colluvium are likely sources for the calcrete cobbles that were used in features at local archaeological sites.

The Mescalero paleosol underlies the sand sheet and is readily available for use in fires at nearly every archaeological site. However, the paleosol has a stage II to III carbonate morphology and is not completely cemented by carbonates. Even though the paleosol is moderately resistant to erosion and forms low escarpments in the area, the paleosol carbonates can be easily crushed by hand. The carbonates of the Mescalero paleosol in the study area are comparatively soft and unsuitable for firing.

The term *caliche* is commonly used in the western Great Plains and Southwest as a convenient synonym for all secondary soil carbonates whether a densely cemented stage IV to VI calcrete or a lesser amount of calcium carbonate accumulation in soils with stage I to III carbonate morphology (Neuendorf et al. 2005; Soil Science Society of America 1997). The form of caliche utilized in hearths at archaeological sites in the Mescalero Sands area is Ogallala Caprock calcrete.

SUMMARY AND CONCLUSIONS

The Mescalero sand sheet is formed by two distinct layers of eolian sand of different ages as determined by optically stimulated luminescence (OSL). The Upper sand is 9,000 to 5,000 years old. Thus, the surface of the sand sheet is about 5,000 years old. Sites younger than about 3000 BC occur at the surface and sites older than 3000 BC are buried within the eolian sand. The Lower sand is 90,000 to 75,000 years old, and sites on the sand unit are deflated although features may intrude into the old sand. Sites in areas where the Lower sand is exposed at the surface are buried by historic-age mesquite coppice dunes. Sites

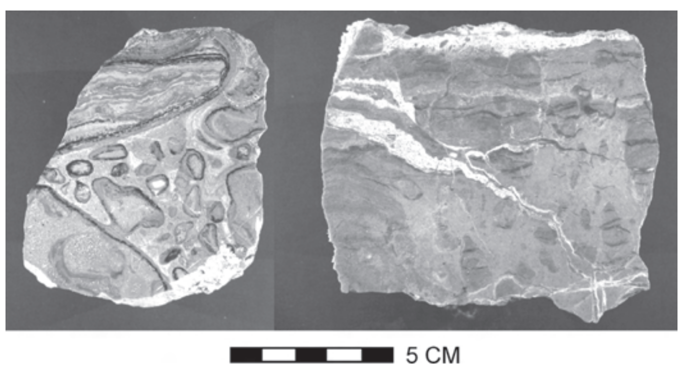

Figure 9. Polished sections of burned Caprock calcrete from an archaeological site; (left) calcrete with pisolitic and laminar features; (right) massive calcrete with dissolution/fill features and fractures filled with secondary carbonates (see Gustavson 1996 for discussion of Ogallala Caprock calcrete).

have high surface visibility but are generally deflated. Sites in the area of the Upper sand are buried by historic-age parabolic dunes. Sites in this area have low surface visibility due to seasonal deposition of eolian sand in partly-vegetated blowouts.

The archaeological geologic map of the Mescalero Sands shows the distribution of areas where sites are (a) at the surface or buried by eolian sand, and (b) exposed at the denuded surface. Paleoindian sites may occur with late Pleistocene cienega and spring deposits west of the High Plains escarpment. These sites may also be buried by the Upper eolian sand unit. Site integrity is partly lost in many cases due to bioturbation by badgers, rodents, and cicada insects.

The burned caliche that occurs at sites is calcrete from the Ogallala Caprock. Caprock calcrete is dense and hard, suitable for firing. Rounded cobbles of Caprock calcrete occur in Pleistocene gravels and colluvium derived from the Caprock escarpment east of the Mescalero Sands. The Mescalero paleosol caliche that underlies the Mescalero Sands is too soft for firing. In areas south of the Mescalero Sands, the Mescalero calcrete is dense and suitable for use in hearths.

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