

Rancholabrean Rubbing Rocks on California's North Coast

by

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Abstract

Unique geological features were recently identified on the Sonoma Coast, approximately 80 km north of San Francisco in northern California. The features consist of highly polished surface areas on Franciscan chert and blueschist outcrops. They are found on vertical rock faces and on overhangs, and from the ground up to a height of 396 cm. Those features found above 200 cm appear older and more weathered than the features found lower down. It is proposed that the outcrops were used as rubbing rocks by large herbivores, and that the polished features are the residue of this rubbing activity. The “rubs” found below 200 cm are thought to have been created (or reused) by cow, horse, and sheep during the historic period, while those occurring above 200 cm are hypothesized to have been produced during the late Pleistocene by now extinct Rancholabrean megafauna such as the Columbian mammoth and ancient bison. This paper is a discussion of the evidence suggesting that the Sonoma Coast features denote Rancholabrean rubbing rocks.

Introduction

On September 12, 2001, during a paleontological survey of Sonoma Coast State Beach, unique features were observed on blueschist and chert outcrops located on the uplifted marine terrace.² The features are highly polished areas (hereafter referred to as “rubs”) that appear to be the residue of animal rubbing activity. The rubs are not randomly located on the rocks. Instead, they indicate a pattern of intentional selection of accessible surfaces, especially those surfaces that are found along intersecting edges or at overhangs, and often on the leeward sides of the rocks. The rubs range from ground level to a height of at least 396-cm. The area was heavily grazed by domestic cows, horses, and sheep during the historic period, and it is thought that the rubs found below 200 cm in height are the product (or reworked product) of historic livestock. However, the rubs occurring above 200 cm are thought to represent prehistoric animal rubs. It is postulated herein that these higher rubs, which appear more weathered than the lower ones, were created during the late Pleistocene Epoch by now extinct Rancholabrean megafauna such as the Columbian mammoth (*Mammuthus columbi*), bison (*Bison antiquus* and *B. latifrons*), and perhaps Harlan’s ground sloth (*Glossotherium harlani*). The Rancholabrean faunas take their name from the famous site of Rancho La Brea (Stock 1956). They are characterized by the appearance of bison (at the Irvingtonian-Rancholabrean transition, ca. 500,000 yr B.P.), and by the presence of many now-

extinct species including bison, camel, mammoth, and mastodon (Kurtén and Anderson 1980; Savage 1951:277).

Sonoma Coast State Beach (hereafter referred to as the “Sonoma Coast”) is a unit of the California Department of Parks and Recreation. The Sonoma Coast is located approximately 80 km north of San Francisco. It measures 2,000 ha in size, and extends from Bodega Bay north to just above the mouth of the Russian River.

The Sonoma Coast is characterized by a wide marine terrace which was originally created by wave action at sea level, and gradually uplifted to its present position beginning about 40,000 years ago (Howard 1979:95; Sloan 2001; Wagner and Bortugno 1982; Wright 1996). The age of the terrace seemingly implies a middle Wisconsinan sea level rise. While such a rise is indicated in studies of the Atlantic continental shelf, it is less obvious in California (cf. Atwater *et al.* 1977:3; Birkeland 1972; Hopkins 1967:50, 79; Milliman and Emery 1968).

The San Andreas Fault is located less than two miles offshore the Sonoma Coast, and the coastline here consists of classic exposures of mélangé, composed of Franciscan rocks, primarily muddy sandstone (graywacke) and serpentinite (Alt and Hyndman 2000:235). Franciscan chert and blueschist (glaucophane schist) outcrops also occur in the area, and comprise the rock material on which have been found animal rubs. Blueschist is a metamorphic material that occurs only in the older Franciscan rocks that were stuffed into the trench deep beneath the Coast Range serpentinite during Jurassic and Cretaceous times (*ibid.*). The southern edge of the Sonoma Coast project area is bounded by Bodega Head, a prominent dioritic land mass. Goat Rock and the mouth of the Russian River bound the northern edge of the project area. The soils located on the upland terraces north of Goat Rock Beach, and near Mammoth Rocks, include Rohnerville loam with intrusions of well-drained Kneeland clay loam soil (Miller 1972).

Historical Background of the Sonoma Coast

The southern half of the Sonoma Coast is located within the former territory of the Coast Miwok, while the northern half was the territory of the Kashaya Pomo. The international boundary dividing the two groups was at Duncans Landing, the site of the Duncans Landing Rockshelter, recorded as archaeological site CA-SON-348/H. The oldest radiometric dates for CA-SON-348/H date to about 8,000 yr B.P., making it the oldest documented human occupation site on California’s North Coast (Schwaderer 1992; Kennedy, Michael, personal communication, 2002).³ In all, over sixty archaeological sites have been recorded within the Sonoma Coast, most of which are late period shellmiddens (Alvarez and Fredrickson 1989).

The area would have been attractive to Paleoamericans. However, as yet, no Paleoamerican archaeological sites have been identified in the Sonoma Coast project area, although a chipped stone crescent was reportedly collected near Bodega Head by a private collector (Fredrickson 1984:516). Other crescents have been found further north along the coast, at both Salt Point State Park and Stillwater Cove Regional Park. Additionally, a fluted point was recovered from near Albion, on the Mendocino Coast (Simons *et al.* 1985). Detecting Paleoamerican presence within the Sonoma Coast project area is made difficult by the buried nature of early deposits in the North Coast Ranges, and the fact that most of the archaeological inspection of the area has consisted of

surface surveys. However, it is likely that a Paleoamerican deposit will eventually be identified in the lower reaches of an archaeological excavation, or perhaps in the trench of a monitored construction project.

A Paleoamerican component is likely to be found at the Duncans Landing Rockshelter (CA-SON-348/H), a multi-component site located on the coastal terrace 6 km south of the Mammoth Rocks. The site has been dated to 8,000 yr B.P. (Kennedy, Michael, personal communication, 2002; Schwaderer 1992). However, the site's earliest known occupation, Component 1, has not been dated. Obviously, it is associated with a time earlier than 8,000 yr B.P. (Schwaderer 1992:59). Given the attractive nature of the rockshelter, the nearby location of abundant resources, and the evidence (albeit slight) of Paleoamerican presence in the area, a reasonable case can be made that Paleoamericans utilized the shelter at least once. Future investigations will need to address the earliest occupation of the site.

Unlike the local archaeology, the paleontological resources of the Sonoma Coast are relatively unstudied. However, there have been a few previous paleontological discoveries. These include the partial remains of a mammoth⁴ (West, James, personal communication, 2001), and a fossil conifer deposit,⁵ both located near Bodega Head. The deposit contains fossil cones of Monterey pine (*Pinus radiata*). Other Rancholabrean-era fossils have been found throughout Sonoma and Marin Counties, including a nearby site on the Estero de San Antonio, about 1.5-km from Bodega Bay, which included the remains of mammoth, mastodon, and bison (Jefferson 1991:50; Savage 1951:283).

The Evidence for Rancholabrean Rubbing Rocks

In an area extending from Duncans Landing north to Goat Rock, and from State Highway 1 to the beach, an area measuring about 8 km north to south, and 500-750 m east to west, there are several additional sites with rubbing rocks. The sites include both blueschist and chert outcrops. Most of the rubs are situated on the leeward sides of the rocks, and only along surfaces that could have been easily accessed by herbivores. The most impressive of these other sites is found near Furlong Gulch, where a red chert (jasper) outcrop has been highly polished. However, all of these other sites consist of relatively minor rubbing and none of it higher than 150 cm or so. It is likely that many of these other rocks have been rubbed in historic times by domestic livestock, which were numerous on this part of the coast until the late 1970s. The Furlong Gulch site appears to be an exception as it appears to have been used in ancient times as well. However, this site does not approach the complexity of the primary site, located 3 km to the north, which the author has named "Mammoth Rocks."⁶

The Mammoth Rocks site is located on the coastal terrace between Shell Beach to the south and Blind Beach to the north. The site sits beneath Peaked Hill. Mammoth Rocks consists of three loci of rubbing rocks, occurring about 400 m apart. The area is characterized by two prominent rockstacks surrounded by boulders of Franciscan mélangé and blueschist. The rockstacks are well known landmarks, and have been depicted in various publications devoted to the local geology (e.g., Alt and Hyndman 2000:236; Bowen 1951:Figs. 6-7).

Locus 1 is a 20-m tall rockstack composed primarily of blueschist. The rockstack is fractured, with several distinct spires rising up from the terrace. The broken nature of the rockstack provides numerous vertical faces and overhangs, on which numerous rubs occur. There is a central open-air “chamber” created by the sections of rock. This chamber may have been favored by herds of herbivores, as it provides some protection from the prevailing winds. Some of the most polished surfaces are found in and around the chamber.

Locus 2 is a 32-m tall rockstack comprised of blue schist and other schistose materials. It is located approximately 400 m south of Locus 1. There is a minor amount of polish on the north side of the rockstack, both on the main stack itself, and on at least one boulder at its base. Some of the polish extends up to about 250 cm high. A small prehistoric shellmidden (CA-SON-1715) is located on the leeward side of the rockstack.

Locus 3 is a blueschist boulder located approximately 40-m northeast of Locus 2. The boulder measures about 10 m in diameter and 3 m high. The northeastern side of the boulder has been heavily rubbed up to a height of about 250-cm. A large slab of rock has broken off from the rubbed area of the boulder, and is now resting on the ground nearby. The slab was rubbed before breaking off from the parent rock.

The rubs at Mammoth Rocks, and those found at the other Sonoma Coast sites, occur only on rock faces that herbivores could have accessed. The rubs vary in height from ground level to 396 cm. The lower rubs appear more polished and fresh than those do higher up. Domestic cattle and horses have a shoulder height of fewer than 200 cm so it is likely that the lower rubs (under 200 cm) can be attributed, at least in part, to historic grazing patterns. The area was heavily grazed until only a few decades ago. Historically, it was part of the old Wright Ranch, dating from the 1870s (Alvarez and Fredrickson 1989:24; Thompson 1877). But whereas the lower rubs are probably the work of cows and horses, the higher rubs (200-396 cm) appear to predate the historic grazing of domestic animals. The majority of the higher rubs cluster at 300-350 cm with a few being found as high as 396 cm.

A slight depression occurs between the two main loci at Mammoth Rocks, and is characterized by wetlands plant species. The depression is about $\frac{3}{4}$ ha in size, and is found about equal distance between the two loci (which are about 400 m apart). The depression occurs along a small but moderately carved drainage, and appears to be unique for the area. Unlikely as it might be, the feature will be examined as a possible fossil remnant of an earlier Rancholabrean wallow and watering hole. At 15,000 yr B.P. the project area probably marked the interior edge of a broad coastal grassland (or savanna) that may have been many miles wide, incorporating several terraces currently submerged. Given that the rock stacks would have been visual landmarks, and that they existed near the ecotone defined by the postulated coastal grasslands/coastal hills confluence, it is likely that they received attention from herd animals. In Africa, elephants often rub as a follow-up to their bathing routine. Elephants have a huge impact on the landscape, as they dig for salt and minerals, and enlarge watering holes to provide better access. Mammoths are assumed to have had very similar habits (Haynes 1991:56, 106-107; Mol *et al.* 1993:6).

The heaviest rubbed areas are the edges or apexes of intersecting rock walls and faces. There are numerous rubs on broad vertical faces, but almost all of the accessible (and leeward) apex edges are rubbed. This is a strategy that can be observed firsthand by watching domestic horses and cows rub

against objects. By leaning against the apex of the rock, they are concentrating the weight of their body against the smallest area of resistance, thus maximizing the effect. This kind of rubbing may have a different purpose than when an animal rubs the bulk of its body against a broader and flatter surface. Evidence of both types of rubbing is found at Sonoma Coast.

On October 4, 2001, the author conducted an auger test excavation in and around Mammoth Rocks. A small twist auger with a 10-cm diameter bucket was used. Five bores were placed within Loci 1 and 2. Two of the test bores were adjacent to a small boulder with rubs at Locus 2. These bores went to depths of 48 cm and 80 cm before hitting large rocks. In both cases, the soil was a dark brown fine sandy loam with small pieces of schist and a few chert pebbles. Two other test bores were made within the inner chamber area of Locus 1, near a rubbed wall. These tests went to 30 cm and 48 cm before hitting rock. Again, the soil was a dark brown fine sandy loam with small pieces of schist and some chert pebbles. The fifth, and perhaps the most important, auger test was made 150 cm from a heavily rubbed overhanging rock on the leeward side of Locus 1. The auger test was located approximately 33 m and 251° from primary site datum, TBM11, at a surface elevation of 133.68 feet above mean sea level. The bore went to 65 cm before being stopped by a rock. From 0-50 cm, the soil was a dark brown fine sandy loam with a few small chert pebbles. The soil became compacted at about 50 cm, and remained that way to 65 cm, at which point the test ended prematurely due to a rock obstruction.

While it would be unwise to conjecture too much based on a single auger test, it seems possible that the indurate level (i.e., 50-65+ cm) encountered in the fifth auger test represents an earlier surface that was compacted by the concentrated weight of herd animals (either domestic cattle from the past century, or perhaps by much earlier Rancholabrean megaherbivores). The topography of the immediate area does not lend credence to the notion that a recent historic surface could have become buried beneath 50 cm of sediment. It is more likely that the compaction indicates a paleosol, or a hardened transition zone between the topsoil and subsoil. If it is a paleosol, its association with Rancholabrean times has yet to be determined.

The History of the Marine Terrace

Examination of the soil profiles evident in the exposed sea cliffs immediately west of the Mammoth Rocks site yields visual clues to the history of the marine terrace. Dark brown topsoil, consisting of sandy loam, occurs from the surface down to an average depth of 50 cm. This upper stratum consists of Holocene-era alluvium deposited during the past 10,000 years. Below the topsoil is yellow sandy subsoil, occurring to an average depth of approximately 220 cm. The subsoil dates to the late Pleistocene, and may represent dune deposits. The base of the subsoil dates to the initial uplift of the terrace at about 40,000 yr B.P. or perhaps to the end of the middle Wisconsinan interstade at about 25,000 yr B.P. Below the subsoil is a stratum of yellow sand with pebble lenses. This stratum is several meters thick, and represents late Pleistocene beach deposits. Below it is a cobble and boulder zone with a matrix of fine sand and gravel. These are also Pleistocene beach deposits, which originated with the cutting of the late Pleistocene bench by wave action about 100,000 years ago, during the Sangamon Interglacial.

The Sonoma Coast marine terrace uplifted out of the ocean during the late Pleistocene, beginning about 40,000 yr B.P., and has been dry ever since (assuming it wasn't inundated by the

Wisconsinan interstade of 48,000-25,000 yr B.P.). The area was probably dry during the early Wisconsinan Glaciation, between 70,000-48,000 yr B.P., when the late Pleistocene wave-cut bench was exposed due to sea level drop. It was also dry off and on during the Illinoian Glaciation of 500,000-130,000 yr B.P. Theoretically, the two large rockstacks that comprise Loci 1 and 2 of the Mammoth Rocks site were exposed and available to animals during much of that time. The rocks would have been especially attractive to megaherbivores between 25,000-15,000 yr B.P., as the late Wisconsinan drops in sea level hit its lowest point. During this time, the Sonoma Coast was characterized by a broad, lush coastal plain, backed by the coastal hills, at the foot of which sat the Mammoth Rocks site.

The only mammal that ever lived on the coastal plain that could rub against rocks 396 cm high was the Columbian mammoth (*Mammuthus columbi*), a species that went extinct 10,000 years ago (Agenbroad 1984:104). A fossil mammoth tusk, lower jaw, and tooth were recovered from Bodega Head in 1972 (West, James, personal communication, 2001). There are other mammoth sites known from the area (Naidu, Raj, personal communication, 2001).

A system of major animal trails once crisscrossed Rancholabrean California. The state's earliest Native American inhabitants likely adopted some of the trails, especially those used by mammoths. Many of the Native American trails were later adopted as pioneer trails, and then converted to paved highways during modern times. State Highway 1, in the vicinity of the Mammoth Rocks, follows a known Native American trail (Davis 1961). It is not unlikely that the route of the highway follows an ancient mammoth trail that traversed north and south along an important ecotone, the conjunction of the broad coastal plain and the coastal range.

At the height of the Wisconsinan Glaciation, 20,000-15,000 yr B.P., sea levels were about 128 m below current levels (Milliman and Emery 1968:1123). During that time, the shoreline of San Francisco was 35 km further west than today, past the Farallon Islands (Bickel 1978:8). As the Wisconsinan ended, sea levels rose rapidly as a result of large-scale ice melting. The average sea level was 128 m lower at 15,000 yr B.P., 56 m lower at 10,000 yr B.P., and 18 m. lower at 7,000 yr B.P. (Milliman and Emery 1968). Sea level stabilized at 6,000 yr B.P., at which time coastal erosion began to carve away the shoreline. It is likely that close to 1 km of the Sonoma Coast, in the vicinity of Mammoth Rocks, has been lost to erosion since 6,000 yr B.P. At that rate, the retreating shoreline will cross the coastal terrace, perhaps reaching the foot of the coast range by A.D. 12,000. Of course, the effects of Global Warming may bring about a new ice age long before that time, relocating coastal erosion further to the west as sea levels drop once again.

At 15,000 yr B.P., the Sonoma Coast consisted of a broad coastal plain extending from the glacial mouth of the Russian River south to Bodega Head and beyond. At the time, the plain extended at least 10-15 km west of the current coastline (Minard 1971:141). It was characterized by a series of coastal terraces. Divers have confirmed the existence of a submerged terrace immediately west of the current coastline at Shell Beach (Wright 1996). Additional Wisconsinan-era marine terraces should be found in deeper waters. Indeed, five submerged terraces, all dating to less than 83,000 years, have been identified off the coast of Fort Ross immediately north of the Sonoma Coast (Prentice 1989:133). While most of the terraces are only a few hundred meters wide, in certain places they can be as wide as 1-3 km (Howard 1951). The submerged terraces serve as mute testimony to Wisconsinan fluctuations in sea level (cf. Moratto 1984:32).

During the late Pleistocene, the ancestral valley of the Russian River in the vicinity of its current mouth was cut at least 125 feet below present sea level (Higgins 1952:241). The filling in of this deep canyon indicates that a large amount of sand and gravel was moved to the coast during the Pleistocene/Holocene transition (Minard 1971:146).

To the southwest of Bodega Head lies Bodega Canyon, a submarine canyon located off the mouth of Tomales Bay, at the edge of the continental shelf (Norris and Web 1990:460-461). Silt and clay particles washing down the Russian River are transported into the canyon (Demirpolat 1991). However, the feature appears to represent a seismic scar rather than the bed of a former river drainage. During the height of the Wisconsin Glaciation, the eastern portion of the canyon may have been exposed above sea level. A portion of Bodega Canyon was mapped in Transit 1A of a 1998 bathymetry and backscatter survey conducted by the Monterey Bay Aquarium Research Institute. The map can be viewed online at: www.mbari.org/data/mapping/margin/Transit_1AtoH.htm.

Although glacial California was typically cooler and wetter than at present, the coastal area enjoyed weather not unlike today's, including dry summers and wet winters. At 15,000 yr B.P., the weather of the Sonoma Coast was probably similar to that found today 300-400 km further north, as indicated by fossil plant remains (Chaney 1951:199). Although it was somewhat cooler than today, coastal California did not experience the severe changes in weather patterns experienced elsewhere in North America during the late Pleistocene.

With its Mediterranean climate, coastal California served as a late Pleistocene refugium for plants and animals (Johnson 1977b). While a paleobotanical reconstruction has not been done for the Sonoma Coast, it is likely that grassland and/or savanna environments once characterized the now submerged coastal plain. The interior edge of the present day coastal terrace was probably characterized by coniferous forest, similar to that identified further south in western Marin County. A closed-cone pine forest dominated by Monterey pine (*Pinus radiata*) characterizes the well-known late Pleistocene Millerton Formation from Tomales Bay (Mason 1934). Dated to approximately 30,000 yr B.P., the forest included various other woody and herbaceous plants found in the area today, including trees such as California nutmeg (*Torreya californica*), Douglas fir (*Pseudotsuga taxifolia*), Bishop pine (*Pinus muricata*), red alder (*Alnus rubra*), coast live oak (*Quercus agrifolia*), pepperwood (*Umbellularia californica*), big-leaf maple (*Acer macrophyllum*), and madrone (*Arbutus menziesii*) (Chaney 1951:199; Lipps and Moores 1971:81-82).

At Point Reyes, a closed forest environment, dominated by fir, appears to have been replaced by coastal scrub and grassland about 10,000 yr B.P. during the Pleistocene-Holocene transition (Rypins *et al.* 1989). Further conversion of forest to coastal scrub and grassland at Point Reyes at the beginning of the historic period has been attributed to the effects of increased grazing (Russell 1983). A change from forest to grassland at Point Reyes around 10,000 yr B.P. is almost certainly a reflection of climatic changes experienced during the Pleistocene/Holocene transition. And a similar pattern at the beginning of the historic period is probably more a result of forest clearing to facilitate grazing, rather than the actual grazing itself.

What We Know About Rancholabrean Grazing Patterns

Edwards (1991) has noted that Rancholabrean grazing patterns would have served to maintain grasslands during the late Pleistocene. The hooves of herbivores, especially horse and bison, helped to aerate the soil, allowing for a more healthy grassland environment. Thus, the disappearance of these herbivore species by 10,000 yr B.P., in addition to the environmental changes of the Pleistocene/Holocene transition, may account in part for the expansion and contraction of grasslands and forests.

During the late Pleistocene, California's grasslands and savannas were undoubtedly teeming with wildlife, including numerous herds of megaherbivores. This "grazing-browsing-trampling megafauna" would have had a serious affect on the development of California's environments, including the San Francisco Bay area and the Central Valley (Edwards 1991:4). For example, African elephants are known to convert woodland into savanna environments by their feeding activities (Owen 1981:48). The mammoth would almost certainly have had a similar effect. Other Pleistocene animals, such as horse and bison, would have nibbled non-grass plants, including the young buds of trees encroaching on the grasslands, thus helping to maintain the health of the grasses. The copious amounts of urine and dung they deposited on the landscape would have served to help fertilize and promote healthy plant growth.

The feeding behavior of California's Pleistocene-era herbivores affected the landscape in other ways as well. As mentioned earlier, the presence of bison and horse herds would have served to help aerate the soil of the grasslands, by the trampling of their hooves, thus allowing for a more healthy grass growth. The herds would have almost certainly moved on before the trampling became destructive to the landscape.

The historic bison of the American Plains were nomadic grazers, seldom spending more than a day or two at any location (Elms 1986:44-45). A similar pattern can be inferred for California's Pleistocene-era bison and horse herds. Thus, it is likely that the mere presence of herds of large herbivores would have prepared and maintained the Pleistocene landscape for grazing. Indeed, in Russia's futuristic "Pleistocene Park," wild horses and bison have been reintroduced to the Arctic landscape for the purpose of "preparing" the land in the event a mammoth is ever cloned and in need of a suitable rangeland (Stone 2001:176-182).⁷ The introduced herbivores have already begun to transform Pleistocene Park's moss-covered tundra to a more suitable "mammoth steppe" grass and sedge dominated environment.

Observations of Herbivore Rubbing Behavior

The only area of the world that in recent times has had a megafaunal menagerie comparable to that of Pleistocene California is in eastern and southern Africa (Edwards 1991:4). In southern Africa, rubbing stones are common in the savanna and grassland areas (Ouzman, Sven, personal communication, 2001). According to one South African researcher,

They stand as monuments to ancient itches. Rocks rubbed to a shine by massive rhino rumps. Boulders polished to brightness by itching elephants. Stones worn smooth with the

scratching of buffalo and bushpig. Rubbing stones glint in desert and forest, savanna and grassy highland all over southern Africa (Skead 1976:21).

African herbivores, including elephant, rhino, zebra, and buffalo, create rock rubs, usually at the conclusion of bathing activity. The rubbing rocks are used primarily to rub off mud and ectoparasites (Smithers 1983:560-564). Similar animals were found on the Sonoma Coast during the late Pleistocene (except for the rhino, *Teleocerus*, which disappeared during the middle Pliocene), so it is not surprising that Rancholabrean rubbing rocks should be found there as well.

Rubbing is a basic grooming behavior for African elephants (*Loxodonta africana*), and they often rub against rocks, tree trunks, and termite mounds (cf. Benyus 1992:116; Eisenberg 1972:191; Eltringham 1982:180-181; Estes 1990:225, 262; Freeman 1979:66; Groning and Saller 1998:90). Following a mud bath, elephants rub against boulders in order to relieve itches that cannot be reached with the trunk, and to remove ticks and other irritating ectoparasites. Historically, wild Asian elephants did the same, as illustrated in this 19th century hunting account.

One large tree grew within fifty yards of the extreme point of the promontory, and another of the same kind grew at an equal distance from it, but nearer to the main land. Upon both these trees was a coat of thick mud not many hours old. The bark was rubbed completely away, and this appeared to have been used for years as a favourite rubbing-post by some immense elephant. The mud reached full twelve feet up the trunk of the tree, and there were old marks far above this which had been scored by his tusks. There was no doubt that one of these tank rogues of extraordinary size had frequented this spot for years, and still continued to do so, the mud upon the tree being still soft, as though it had been left there that morning (Baker 1854).

The hunter's account continued with his sighting a large elephant that suddenly appeared at the lake to bathe. Following his bath, the elephant proceeded to the rubbing tree, and rubbed against it. Shortly afterwards, he was killed by the concealed hunter.

Herds of zebra (*Equus spp.*), once including the now extinct quagga of South Africa, also utilize large rocks, tree trunks, and termite mounds for rubbing (Benyus 1992:121; Iwago 1996:194; MacClintock 1976:80-81, 112). On the Serengeti, where rubbing rocks are scarce, zebras will stand in line for their turn to rub (Estes 1990:236; Iwago 1998:377). Various other large African herbivores exhibit rubbing behavior as well, including the rhinoceros and giraffe (Benyus 1992:137, 145). Occasionally, South African rock art is found in association with rubbing stones (Ouzman 1996a:40, 1996b, 2001).

Some of the best known rubbers are bison. Numerous accounts exist regarding the rubbing behavior of North American and European bison, who rubbed against rocks, among other things (e.g., telegraph poles, sod houses, etc.), to relieve itches and ward off flies (Bourliere 1954:104; Cahalane 1961:78).

Everyone agreed that a buffalo loved to wallow and loved to rub, especially during the summer. He wallowed in mud or dust to try to protect his hindquarters, shed almost to nakedness, from biting insects. He rubbed against boulders and trees to relieve the itch of

insect bites and to remove matted winter wool. He rubbed until he polished stone surfaces “smooth and lustrous as polished mahogany” and wore a trench about them even as he greased them with wool fat; he rubbed until he peeled sections of bark from young lodgepole pines, leaving shaggy tufts of brown wool hanging at the edges of the scars; he rubbed until he killed all of the young trees bordering a wallow (Barnes 1985:15).

Bison rubbing stones are mentioned in various accounts from the Great Plains (Dary 1989:41; Elms 1986:43; McHugh 1972:150-151; Monaghan 1963:432). Today, some of these stones can still be seen, especially in the Canadian Provinces of Alberta and Saskatchewan.⁸

In addition to the rubbing stones, old bison wallows can still be seen on the Great Plains in areas that have escaped plowing and development. In the past, the Plains bison created wallows for the purpose of taking dust baths. Wallowing afforded some relief from flies and other insects, especially in mid-summer when the bison had little protective hair on their hind quarters (Sample 1987:49). These wallows were used year after year, and some of them measured 10 m across and 1 m deep (Elms 1986:43). Male bison increased their wallowing during the rutting season (McHugh 1972:196-198).

Plains bison were especially fond of prairie dog communities, as the dog towns afforded them expanses of exposed and soft earth on which to wallow (Sample 1987:63). Today, the Mammoth Rocks vicinity is characterized by the burrows of both badgers and gophers, both of which were present during the late Pleistocene (Kurtén and Anderson 1980: 157-158, 223-229; Stock 1956:35, 41). It is likely that a similar relationship existed between these burrowing animals and *Bison antiquus* and *B. latifrons*.

Megaherbivores are not the only animals that rub themselves against solid objects. Bears claw trees to create signs, and rub against trees in order to relieve itches (Storer and Tevis 1955:52). Peccary rub against tree trunks and overhanging limbs so as to leave their scent (Elms 1986:78). Similarly, male deer create scrapes on small saplings in order to leave their scent markings (Rue 1997:204-212; 2000:64-71, 120).

Feral pigs also enjoy a good rub. Recently, in the San Francisco Bay area, a Native American painted cave was discovered. The cave is filled with red pictographs comprised mostly of abstract figures. Some of the painted elements extend down to ground level. At the time of the cave’s discovery, wild pigs were found inhabiting the site. Unfortunately, they had rubbed some of the paintings off of the cave’s lower walls.⁹

Domestic horses, cows, and sheep are notorious rubbers. They use various objects, including fence posts, trees, and rocks, to relieve itches and ward off flies and other annoying insects. More than a few dismounted riders have been used as rubbing posts by their horses.

Rancholabrean Species that Probably Utilized Rubbing Rocks

It is likely that a variety of Rancholabrean species utilized rubbing rocks. In such cases, an animal’s height is important to a discussion of animal rubs. An animal standing 200 cm or less at the

shoulder, like domestic cows, horses, and sheep, obviously could not have created rubs 396 cm above the ground surface, providing there has been no catastrophic ground erosion during the historic era. However, Rancholabrean megaherbivores, such as the Columbian mammoth, could have rubbed at higher elevations on local rocks. The following Rancholabrean species are likely to have utilized rubbing rocks within the project area:

- *Mammuthus columbi*. The Columbian mammoth stood as high as 390-430 cm at the shoulder (Agenbroad 1998: 6; Harris and Jefferson 1985:26; Kurtén and Anderson 1980:351; Mol and Agenbroad 1994:250), and is known to have occupied the project area. *Mammuthus sp.* remains were recovered from a location near Bodega Head in the early 1970s (West, James, personal communication, 2001), and other mammoth sites are known from elsewhere in the area (Jefferson 1991:50; Naidu, Raj, personal communication, 2001; Savage 1951:283, 285).¹⁰
- *Mammuth americanum*. The American mastodon stood about 200 cm at the shoulder (Harris and Jefferson 1985:27; Jefferson 1988:96). Mastodon remains have been found at several locations within the region (Jefferson 1991:50, 94-95; Savage 1951:283).
- *Bison antiquus*. The ancient bison was taller than the modern bison, standing about 210 cm at the shoulder (Jefferson 1988:98). *Bison sp.* remains have been found at several locations within the region (Jefferson 1991:50, 94-95; Savage 1951:283).
- *Bison latifrons*. The long-horned bison was taller than *B. antiquus*, probably standing about 250 cm high (Jefferson 1988:97). It went extinct earlier than *B. antiquus*, around 27,000 yr B.P. *Bison sp.* remains have been found at several locations within the region (Jefferson 1991:50, 94-95; Savage 1951:283).
- *Equus occidentalis*. The western horse stood about 150 cm high (Jefferson 1988:96). *Equus sp.* remains have been found at several locations within the region (Jefferson 1991:94-95). *Equus conversidens*, which was slightly smaller than *E. occidentalis*, may have also inhabited the area, as did *Equus pacificus*.
- *Glossotherium harlani*. The Harlan's ground sloth stood about 180 cm high (Jefferson 1988:96). *Glossotherium sp.* remains have been found at several locations within the region (Jefferson 1991:50, 94-95; Savage 1951:283).
- *Camelops hesternus*. The camel stood about 230 cm high at the shoulder (Jefferson 1988:97). *Camelops sp.* remains have been found in at least one location in the region, at Ebibias Creek near Valley Ford (Meyer, Jack, personal communication 2001).

Other Known or Suspected Rubbing Rock Occurrences

Hueco Tanks State Park in Texas is a large igneous rock formation characterized by numerous archaeological sites including rock art. The area also contains naturally occurring rock basins, or "tanks," which hold freshwater. Archaeologists working there in 1999 tentatively identified what they believed to be mammoth rubs on some of the rock surfaces (Berrier, Margaret, personal communication, 2001). The rubs occur in two loci, and are about 300 cm above the ground.

However, on further examination, the researchers decided that the rubs were most likely made the rubbing activity of domestic cattle. They explain the great height of the rubs by suggesting that erosion has lowered the surface since the time the cows created the rubs. If the rubs were created by cows rather than the mammoth, the ground level would have had to erode at least 150 cm in less than a century. Some of those who are familiar with the site believe it is unlikely that erosion has lowered the surface that much. Instead, they believe that mammoths and/or other megaherbivores may have created the rubs that are found there (McCulloch, Jim, personal communication, 2002). Since the presence of water-holding tanks would have attracted numerous animals to the area, it is possible that the rubs at Hueco Tanks were created by a variety of animals, including RanchoLabrean megaherbivores, modern bison, and, most recently, domestic cattle. More work is needed at the site to fully understand the nature of the polished features.

Located about 50 km west of Hueco Tanks is the site of Cornudas Mountain, New Mexico. Like Hueco Tanks, Cornudas Mountain is an igneous formation characterized by naturally appearing rock basins that hold fresh water. In 1941, Dr. Walter Lang, a geologist with the United States Geological Survey, visited the site and identified what he believed to be animal rubs.

Recently while engaged in making geological observations in the Hueco and Cornudas Mountains of western Texas and New Mexico I became aware of the repeated occurrence of large highly polished patches of rock which had escaped my notice before this. The Huecos and Cornudas, like other granitic intrusive masses, upon weathering have developed large open fractures, niches and even sizable caves, many of which have openings at the level of the ground. There was observed at the entrance to one of these small crevice caves a highly polished rock surface on the hanging-wall side. The footwall, however, showed the same rough weathered appearance as the inner and outer surface about the polished area. Subsequently it was found that at practically all other slanting cavernous openings, the polished surface, if present, appeared on the hanging-wall side. I do not recall having seen polished surfaces upon rocks which were high above the ground surface or upon the tops of rocks.

Later I was surprised to see the same type of polished surface on the sides of large outlying boulders, some fifteen to twenty feet in diameter, which had broken loose from the high cliffs and had tumbled out onto the surrounding apron of detrital wash. My recollection is that most of these polished areas are on the south side of the boulders and near their edges or corners. It was noted that all the patches are similar in size and position. They begin at a point about two feet off ground, often extending to a height of seven to nine feet and seldom cover a space more than five to ten feet wide, whether at the entrance to openings or on isolated boulders (Lang 1941:390).

Lang returned to Cornudas in 1946, and took a single sample of the glassy polish for analysis. The analysis revealed that the surface was coated with an opalized silica measuring about 0.5 mm. To determine whether animal oil or fat was present, a sample of the rock was broken into fragments, treated with carbon bisulfide, and evaporated in a porcelain dish. Even though only a small amount of rock had been tested, “a very sizable spot of honey-yellow oily matter remained on the porcelain dish” (*ibid.* 1947:65). Lang deduced that:

the fine silica dust mixed with oily fats was rubbed on the surface of the rocks by animals, and that in the decades, if not centuries, of exposure to the elements since the last animal used the rock for a rubbing post, the silica weathered to opal, and the oil gradually vanished from the surface film. As the oil distilled away in the heat of the sun, the film shrank, and the residuum of opal formed a shriveled and mummified skin on the face of the feldspar phenocrysts (Ibid.).

Lang speculated about the animals that created the Cornudas rubs, noting that the rubbed overhangs would have been handy for animals of all sizes, including “ground sloth, elephant, bear, antelope, etc.” (1941:390). The longtime owners of the site believe that mammoths created the upper rubs, as they are located too high on the rocks to have been created by cows (Jim McCulloch, personal communication 2002).

In October 1947, another geologist, Chapman Grant, visited Cornudas Mountain in response to the two articles that Lang had published in *Science*. Grant went there in order to collect a sample of the rock polish so as to test Lang’s hypothesis. Grant felt that the “oil” that Lang recovered from the rock was the result of contamination. Grant was unable to relocate the features described by Lang, and determined (apparently incorrectly) that Lang’s polished features had been created by the natural action of water during wetter times (Grant 1948). However, according to Jim McCulloch (personal communication 2002), who is familiar with both the Cornudas Mountain and Hueco Tanks sites, Grant apparently failed to find the polished rocks described by Lang, as Grant’s account of the rocks differs significantly from Lang’s description (and McCulloch’s personal observations).

Alamo Mountain, located just a few kilometers west of Cornudas Mountain, and Akela Flats, a rock art site located near Las Cruces, New Mexico, are both characterized by polished surfaces that are thought to have been created by ancient megaherbivores (Leroy Unglaub, personal communication 2002). Other rubbing rock sites are known from southern New Mexico, the El Paso, Texas area, and northern Mexico (McCulloch, Jim, 2002, personal communication). A possible rubbing rock is located at Rock Springs in Wisconsin, and depicted in photographs at a web site devoted to the site (<http://www.uwgb.edu/dutchs/geolwisc/geostops/rockspr.htm>). Rubs have also been posited for a number of cave walls and entrances from caves with Pleistocene ground sloth remains in the Southwest, and at Gypsum Cave in Nevada (West, James, personal communication, 2001).¹¹ Buffalo rubbing stones are relatively well known on the American Plains, especially in the Canadian Provinces of Alberta and Saskatchewan.¹² One of the rubbing rocks, located near Aylesbury, Saskatchewan, is pictured in *Heads, Hides & Horns* by Larry Barsness (1985:16). Rubbing rocks are also known from Africa, where they are still utilized by elephants and rhinos (Haynes, Gary, personal communication, 2002; Sven Ouzman, personal communication 2001). However, whereas rubbing rock sites are known to occur elsewhere, few, if any, have been documented as such.

Future Research at the Mammoth Rocks Site

Further research is necessary in order to test the hypothesis that the Mammoth Rocks were utilized as rubbing rocks by Rancholabrean megaherbivores. The research will take several forms.

First, it will be important to determine the geomorphology of the site. Given the configuration of the landscape, there may have been relatively minor surface fluctuations over the past 12,000 years. In fact, it is possible that the modern surface is no more than 100 cm higher or lower, in relationship to the rubbing rocks, than it was during the late Pleistocene. As the area appears to have been characterized more by depositional than erosional history (Jack Meyer, personal communication 2001), it is likely that the surface was slightly lower at 15,000 yr B.P. This may explain the buried compacted layer at 50 cm should it prove to be a paleosol from Rancholabrean times. However, if the upper rubs (at 396-cm height) can be attributed to Rancholabrean herbivores, including mammoth, the height of the features may indicate periodic erosional episodes within a generally depositional history.

Second, it will be necessary to sample the rub locus and the general terrace area to determine whether pertinent evidence exists within the fossil plant phytolith record. Like modern elephants, mammoths required an enormous quantity of food, probably more than 350 kg per day, and may have spent up to twenty hours a day feeding (Lister and Bahn 1994:77; Mol *et al.* 1993:7). The typical elephant produces between 140-180 kg of dung per day (Agenbroad 1993:7). The Columbian mammoth probably produced considerably more. Like modern elephants, mammoths digested less than half of what they ate, thus mammoth dung contains a high amount of unprocessed vegetal matter (Mead *et al.* 1986; Mol *et al.* 1993:7). Based on the analysis of mammoth dung recovered from the arid American Southwest, especially the Colorado Plateau, we know that grass and sedge were the preferred food items (Agenbroad *et al.* 1984; Davis *et al.* 1985; Hansen 1980; Mead *et al.* 1986). Indeed, the analysis of 25 fragments of mammoth dung from Bechan Cave, Utah, indicated that more than 95% of each bolus consisted of a matrix of grasses, sedges, and rushes, with less than 5% consisting of browse items (Mol *et al.* 1993:8).¹³ The Columbian mammoth's heavy dependency on grasses and sedges mirrored the diet of the woolly mammoth elsewhere (Lister and Bahn 1994:76).

Since mammoths selected certain food plants, it may be possible to see evidence of their preference in the phytoliths recovered from in and around the rubbing rocks as compared to the general terrace area surrounding them. This is based on the fact that mammoths produced a large amount of dung a day, with the dung containing a large percentage of intentionally selected (preferred) but largely unprocessed vegetal matter (Agenbroad 1993:7; Haynes 1991:88-89). Thus, if mammoths utilized the rocks as proposed herein, there may be an increased frequency in the presence of phytoliths from mammoth-preferred food plants in and around the rocks, than randomly occurring on the surrounding coastal terrace.

Like mammoths, bison were grazers. Grass comprised 80-90% of the diet of American plains bison (*Bison bison*) studied under natural conditions (Guthrie 1990:176). Modern bison consume some forbs and woody browse, but browse appears to be their lowest choice. A skull of *Bison antiquus*, collected in Sonoma County, has a broad snout suggestive of a grazer (Edwards 1991:4). Late Pleistocene bison dung from Cowboy Cave, Utah was found to contain mostly grasses and sedges (Hansen 1980). At Rancho La Brea, however, the epidermal fragments recovered from bison teeth suggest that *B. antiquus* was primarily a browser, perhaps with a seasonal emphasis (Akersten *et al.* 1988). The isotopic study of fossil herbivore teeth can reveal clues to an area's paleoclimate and vegetation. Future analysis of the mammoth, mastodon, and bison teeth recovered from Bodega

Head and nearby Estero de San Antonio may reveal important evidence regarding megaherbivore diet and the paleoclimate and environment of the Sonoma Coast.

Third, it will be necessary to examine the soil in the vicinity of the rubbing rocks. If the rocks have been rubbed to the extent that is proposed herein, animal hair would have been dislodged in copious amounts, some of which may remain to be found in the surrounding soil. In order to test for the presence of fossil hair, an archaeological excavation will be conducted adjacent to the rubbing rocks in Locus 1. The main area to be tested includes the buried compacted layer. The excavation will seek to investigate the nature of the compacted level, and sample for fossil (shed) hair, evidence of footprints, or any other physical evidence indicating the presence of now-extinct Rancholabrean megafauna.

The actual footprints of Rancholabrean species have been recorded elsewhere, including bear tracks in Oregon, camel tracks in Arizona, New Mexico, and Alberta, mammoth tracks in Arizona, South Dakota, Alaska, and Alberta, and musk oxen, horse, and bison tracks in Alberta (Anonymous 1999; Hall 1999; Laury 1994:55-56; Lea 1996; Lockley and Hunt 1995:274-277). Mastodon tracks dating to the middle Pliocene were reportedly found on the bottom of a shallow lake at Saint Mary's College in the eastern San Francisco Bay area (Stirton 1951:185-186). Rancholabrean tracks tend to be found around the margins of Pleistocene-era lakes and wetlands, south of the glacial ice sheets. While it is unlikely that similar footprints will be found at Mammoth Rocks, there are some scenarios that might explain their presence. For example, if the last Rancholabrean megaherbivores to utilize the rubbing rocks stood on the ground surface while it was wet, they would have left deep footprints typical of their weight. If the animals then abandoned the site, which later dried out, those final footprints would have dried out as well. It is conceivable that the hardened prints were later buried beneath sediments, and may still be there to discover. A second scenario, perhaps better suited to the long-term preservation of footprints, would have the megaherbivores standing on a compacted surface (e.g., beneath the heavily rubbed overhang) while it was wet. In such a case, the footprints would tend to be shallower than those made on a non-compacted surface, but the fact that the compacted surface itself might survive as a feature could increase the survivability of the prints. Of course, any number of natural events could have destroyed these hypothetical prints, but it may still be worth the effort to look for them.

Fossil (shed) hair may be present at Mammoth Rocks, even if the animals' footprints are not. Its preservation depends in part on the nature of acidic, bacterial, and fungal attacks on the specimen (Bonnichsen *et al.* 2001:777). Hair is durable, and can survive in soils with a pH of about 4.5 or higher (Robson Bonnichsen, personal communication 2002). The pH of the area's topsoil is 5.7 (Brendan O'Neil, personal communication 2002).

The work of Robson Bonnichsen and others has documented the presence and manner of recovering fossil hair in archaeological contexts (Beatty and Bonnichsen 1994; Bonnichsen *et al.* 1996; Bonnichsen and Bolen 1985; Bonnichsen *et al.* 1992, 2001; Ream *et al.* 1999).

During excavation of ancient deposits, hair is difficult to see and often has been discarded. However, hair is a surprisingly durable substance that sometimes survives remarkably long periods of time and occurs in archaeological, paleontological, and paleoecological sites (Bonnichsen *et al.* 2001:775).

For example, work conducted at the Mammoth Meadows site in southwestern Montana has recovered the fossil hair of animals ranging in size from small rodents to mammoths. If hair is identified at Mammoth Rocks, it will be important to recover the proximal ends since it is the hair follicle that lends itself to the extraction of Deoxyribonucleic Acid (DNA). Mitochondrial DNA (mtDNA) is of most interest to molecular biologists studying shed hair (Allen *et al.* 1998; Wilson *et al.* 1994). In addition to being a source of ancient DNA (aDNA), fossil hair can be dated providing the sample is at least 2-4 cm in length (Bonnichsen *et al.* 2001:775; Taylor *et al.* 1995). For example, at the Smith Creek site in east central Nevada, mtDNA was recovered from several bighorn sheep (*Ovis canadensis nelson*) hairs, and dated to 9,800 yr B.P. by radiocarbon analysis (Bonnichsen *et al.* 2001).

Maximum precautions will be required during the recovery of fossil hair, since contemporary contamination constitutes a serious source of errors in aDNA analysis. Therefore, the excavation will be conducted as recommended for a forensics investigation (Wilson *et al.* 1994). If possible, probing will take place at the excavation site, and gloves, safety masks, and other protective clothing will be worn to ensure maximum protection from contamination. If fossil hair is not identified in the field, it will be necessary to send some of the excavated soil to the lab en masse for microanalysis. Sterilized and DNA-free tools and containers will be used to recover and transport the soil. In the lab, the soil will be screened using very fine mesh sieves, and the screenings analyzed under 10-20x magnification

Prior to conducting the archaeological excavation, a geophysical survey, utilizing a Cesium Magnetometer and/or Ground Penetrating Radar (GPR), is necessary to determine whether buried features are present near the rubbing rocks. Such survey will help to identify the presence or absence of compacted paleosols and fossil skeletons.

A geomorphologic analysis is also needed to determine site formation (including landform history and soil profiles). It will be most important to determine the depositional history of the site, so as to evaluate the late Pleistocene height of the rubs. As part of the geomorphologic study, the salinity of the soil will be examined as a step toward determining if mammoths were using the area as a source of salt. African elephants are known to include salt in their diets, and will go to great lengths to obtain it (Grace 1993:24; Jackson 1990:34). Mammoths are also thought to have utilized salt and other minerals (Haynes 1991:92, 96-97). If the Mammoth Rocks environment proves to be hypersaline, the presence of salt may have had a positive effect on the long-term stability and viability of DNA specimens, particularly those found situated in the soil (cf. Grant *et al.* 1998; Jones 2001:232; Letey 1986; Shainberg and Letey 1984; Vreeland *et al.* 1998).

In the past, scientists did not believe that long-term DNA preservation was possible in biological remains, as studies had shown that degradation occurs rapidly (within hours or days) after death. Because DNA-degradation is correlated with the loss of genetic information, no studies to recover genetic information were carried out for a long time. This changed in the early 1980s when intact genetic information was successfully detected in a 4,000-year old Egyptian mummy (Pääbo 1985). At that time, however, molecular biological methods required a high amount of source material, which greatly restricted DNA analysis. Then, in the mid-1980s, the Polymerase Chain Reaction (PCR) technique was invented (Saiki *et al.* 1988). PCR made it possible to detect and amplify

minimal traces of DNA, and thus helped make aDNA research a powerful tool for understanding the past. In some cases, degraded DNA can even be repaired in order to make it suitable for PCR-analysis (Pusch *et al.* 1998). However, one of the biggest problems with using PCR is eliminating modern contamination. Ancient samples can be easily contaminated with extraneous DNA derived from a researcher's hands, hair, or glassware. For this and other reasons, it is very difficult to extract and analyze aDNA.

In recent years, one of the most controversial aspects of DNA research has been the claim of recovering aDNA from amber-preserved fossil insects. The findings have resulted in two schools of thought among scientists. While one group feels it is possible to recover viable aDNA from specimens that are many millions of years old, the other group dismisses their claims as being the result of modern contamination (cf. Aldhous 1996; Hofreiter *et al.* 2001; Jones 2001; McCluskey 2000; Poinar *et al.* 1996; Poinar and Poinar 1994). Part of the problem is that aDNA cannot itself be dated. However, there is agreement that aDNA can be recovered from specimens as old as 50,000-100,000 years (Anonymous 1999; Jones 2001:37; Lindahl 1997). Given the fact that the Mammoth Rocks site has a relatively late Rancholabrean history (i.e., from the initial uplift of the marine terrace at about 40,000 yr B.P., to the extinctions of 12,000-10,000 yr B.P.) any aDNA found there may conceivably be recoverable. Should viable aDNA be recovered, its analysis will be crucial to identifying the kinds of animals that utilized the site.

Finally, it will be necessary to examine the rubs themselves. For this purpose, the author collected three small samples of Sonoma Coast rubs on June 10, 2002, with the assistance of Drs. Steve Norwick and Rolfe Erickson, Professors of Geology at Sonoma State University. The geologists then analyzed the samples. Thin sections were examined under strong magnification, and the polished surfaces by way of Scanning Electron Microscopy (SEM). Drs. Norwick and Erickson have determined that the polish is unlike any natural rock polish they have previously observed (Norwick, Steve, personal communication, 2002). Furthermore, they feel that natural process (such as wind or water erosion) can be ruled out as an explanation for the polished features. Samples of the polish observed at Mammoth Rocks were compared under magnification to the polish occurring on nearby beach pebbles of similar material. The two kinds of polish look very different from one another, and indicate that natural beach processes did not create the polish observed at Mammoth Rocks. Additional comparative samples will be examined by SEM to determine the wear patterns on rubbing stones known to have been used by large herbivores. Requests have been made to obtain suitable rock samples from rubbing rocks used by elephants, bison, and cows in South Africa, Canada, and California respectively. Comparative samples are currently enroute from the Johannesburg Zoo (Rynette Coetzee, personal communication 2002), and additional samples may be made available for several suspected rubbing rock sites in New Mexico as well (Leroy Unglaub, personal communication 2002).

In a recent study, fluorescently labeled protein and DNA were used to document the subsurface penetration of blood into the microcracks of rocks, and a method was developed to recover the biomolecular evidence from the cracks (Ream *et al.* 1999). Given the initial results of the geological analysis of the Mammoth Rocks samples, it seems appropriate to search the Sonoma Coast rubs for aDNA. To do so, it will be necessary to (1) determine whether aDNA samples (such as blood residue, tissue, or hair) were ground into the micro-fissures and cracks of the rock; (2)

whether they still exist as viable DNA specimens; and (3) whether it is possible to recover such specimens for analysis.

Blood residue may be present on the rocks, deposited there by the rubbing of scratched or wounded animals. Blood residue can be used for identifying the species of animals that utilized the rubs. A recent Alaskan study identified mammoth, among other Rancholabrean species, by the blood residues found on Paleoamerican stone tools (Loy and Dixon 1998).

While it is likely that much of the aDNA deposited on the rocks has long since degraded, there are some scenarios that may have facilitated long-term preservation. For example, if aDNA was deposited in micro-cracks, and the rock surface was then covered with a coating of silica, it is possible that the silica would have prevented the DNA from degrading. Lang's (1947) observations from Cornudas Mountain lend support to such a possibility. Indeed, the body oils of megaherbivores should have served as a preservative, as did the clay that was rubbed onto the rocks following a mammoth's bath or a bison's wallow. It is thought that such clay, derived from the mud-encrusted animals, resulted in the high sheen and almost commercial-grade quality of the polish observed at the site today. If aDNA is recovered from the rubs themselves, it should be possible to identify the actual species of animals that created the polished features.

Conclusions

The best interpretation of the Sonoma Coast rubbing rocks is that they represent the prehistoric rubbing behavior of late Pleistocene Rancholabrean herbivores, especially the Columbian mammoth and/or ancient bison. Additionally, a lower assortment of fresher-appearing rubs was probably created by domestic horse, cow, and sheep during the historic period.¹⁴

The Mammoth Rocks appear to have been favored by herd animals. These large rock outcrops provided good shelter from the wind, and were quite likely visual landmarks for animals as well as people. At Locus 1, there is an inner area surrounded by the rocks that could have held numerous cows or bison and mammoth that may prove to be a paleontological site. It is an area that should be tested. An anomaly likely exists in the ratio of fossil plant phytoliths recovered, and to some degree, this may indicate the concentrated presence of grazing herbivores. The skeletal remains of the animals may be located there as well. It has yet to be determined if the soil chemistry is conducive to preservation, or whether the earlier soils are even still present. If they are, it will be important to sample for fossil (shed) hair.

Provided that a Rancholabrean origin can be attributed to the rubbing rocks, they are important for several reasons. First, the rocks may be perceived as points on a map for identifying the former presence of megaherbivores, their seasonal migration patterns, and social behavior. As additional rubbing rocks are identified elsewhere, the "map" will be filled in, and our knowledge increased.

Seasonal migration may prove to be an especially interesting topic. In southern California, the seasonal migration of *Bison antiquus* to Rancho La Brea is indicated by the presence, in Rancho La Brea's fossil record, of numerous young individuals (Jefferson and Goldin 1989). The evidence suggests that, "herds of adult females with young animals were in the Rancho La Brea area for about a month during the late spring and then left the region to forage elsewhere the remainder of

the year (Ibid.:111). Like their southern California counterparts, Sonoma Coast bison would have also practiced seasonal migration. Herds of mammoth probably moved with the seasons as well.

Today, the Roosevelt elk (*Cervus elaphus roosevelti*) of California's North Coast practice a seasonal round following natural productivity. The elk spend the fall through spring in the interior, feeding on nuts (fall), and grasses and forbs (spring), then travel to the coastal prairies in the late spring through summer, where fog drip keeps everything green and lush (Greg White, personal communication 2002). While evapo-transpiration rates would have been elevated (compared to historic times) during the late Pleistocene, a similar east-west movement of Rancholabrean megaherbivores may have connected the Santa Rosa Plains and Petaluma Valley of the interior, with the coastal prairies of the Sonoma Coast. Primary migration routes would have followed the Russian River and Salmon Creek, as well as the Estero Americano and Estero de San Antonio. Most of the North Bay's known Rancholabrean megaherbivore fossils come from the Santa Rosa Plains, Petaluma Valley, Sonoma Coast, or one of the connecting waterways.

Also important are the implications that the identification of Rancholabrean-era rubbing rocks will have for Paleoamerican archaeology. For example, the Mammoth Rocks site may have been a "focus" of Paleoamerican hunting activity (cf. Jefferson 1988). However, as yet, no Paleoamerican archaeological sites have been identified in the Sonoma Coast project area.

Finally, Mammoth Rocks, and sites like it, may prove to be an untapped source of aDNA, both in the ground and within the micro-topography of the rock surfaces. Future efforts at recovering fossil hair from around the rocks, and especially DNA specimens from within the rocks, may prove to be the most important aspect of any future investigation. Should such a source of aDNA exist, it may hold important clues to the past, including the reason(s) why so many of the Rancholabrean species became extinct at the end of the Pleistocene Epoch (especially if the extinctions were in part caused by extremely lethal hyperdiseases).¹⁵

Currently, the rocks at Locus I of the Mammoth Rocks site are heavily visited by rock-climbing enthusiasts, who know the site as "Sunset Rocks." Climbers come to the rocks for the purpose of bouldering and repelling. Apparently, climbers have been coming to the site in ever increasing numbers for 15-20 years. In addition to individual visitors, the site is occasionally the scene of special climbing events authorized by the State. Based on the author's personal observations over the past year, it is estimated that more than 100 visitors climb the rocks every week. The actual number may be several times that amount. To date, the State has not evaluated whether this recreational use has an adverse impact to the resources of the site. The California Environmental Quality Act may sooner or later require such an evaluation.

It is the author's concern that climbing-activities may be adversely affecting the rubs by the introduction of chalk (which climbers use on their hands for a more secure grip), as well as human body oils (from the climbers' hands), directly onto (and perhaps into) the rock. What effect, if any, this has on the chemistry of the rubs is not known. Occasionally, the climbers inadvertently create breakage along the edges of the rubs, by using them as gripping and stepping points. On several occasions, climbers have been observed intentionally removing loose sections of rock in order to improve their climbing safety. Equally distressing is the possibility that over time, climbers may be

creating their own type of polish atop the older polish, thus masking, and perhaps altering, the old rubs.¹⁶

Litter, illegal fires, and graffiti are appearing at the site with increasing frequency, but cannot be attributed to the climbers. Many non-climbers visit the area as well, partly due to the presence nearby of a popular hiking trail. Perhaps not surprising, with few exceptions, the climbers with whom the author has spoken appear to have a genuine concern for the rocks. If their actions are harmful to the rocks, it is from a lack of understanding of the site's significance, rather than any deliberate action on their part. Regardless, it is imperative that the State evaluate the impacts that visitors are having on the site, and take appropriate actions to mitigate any impacts that are deemed adverse, whether it is through public education, resource management, or site closure.

The story of the last Ice Age, including the mammoths and mastodons, and the large-scale extinctions, is of great interest to the citizens of California (cf. Norberg 2002). Someday, the Mammoth Rocks site may prove to be an important resource in the telling of this story. Indeed, if now extinct Rancholabrean megafauna, such as the Columbian mammoth, are proven to have created the rubs, the site will have significant importance as both an interpretive and scientific resource. And should a Paleoamerican component be eventually identified at the nearby Duncans Landing Rockshelter site, or elsewhere on the Sonoma Coast, the State may have the ingredients for a new "Pleistocene State Historic Park" (or "Pleistocene Cultural Preserve") to be created out of a portion of the existing Sonoma Coast State Beach. The Pleistocene Park envisioned by the author is a place that California's citizens and visitors can come to experience and learn about the Pleistocene Epoch. The visible geology of the uplifted Pleistocene terraces and the nearby San Andreas Fault, the Rancholabrean animal rubs, and the Paleoindian presence would combine as powerful elements in the story of the Ice Age. But for now, Pleistocene Park is just a possibility for the future.¹⁷ At this time, it is important that Mammoth Rocks be thoroughly investigated and protected by the State, who holds the site in the public trust as the steward of State Park lands. This report serves as the first step in that investigation, and will hopefully facilitate the State's ongoing site stewardship.

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References Cited

Agenbroad, Larry D.

1984 New World mammoth distribution. In *Quaternary Extinctions*, Paul S. Martin and Richard G. Klein (eds.), pp. 90-108. Tucson: The University of Arizona Press.

1998 *Pygmy (Dwarf) Mammoths of the Channel Islands of California*. Hot Springs, South Dakota: The Mammoth Site of South Dakota.

Agenbroad, Larry D., Jim I. Mead, and Paul S. Martin

1984 Chronology and diet of *Mammuthus* from Eurasia and temperate North America. *Abstracts of the XXVII International Geological Congress*, Moscow.

Akersten, W.A., T.M. Foppe, and G.T. Jefferson

1988 New sources of dietary data for extinct herbivores. *Quaternary Research* 30:92-97.

Aldhous, Peter

1996 Dinosaur DNA fails new test of time. *New Scientist* 150(2030):21.

Allen, M., A.S. Engstrom, S. Meyers, O. Handt, T. Saldeen, A. Von Haesler, S. Pääbo, and U. Gyllensten

1998 Mitochondrial DNA sequencing of shed hairs and saliva on robbery caps: sensitivity and matching probabilities. *Journal of Forensic Sciences* 43:453-464.

Alt, David D., and Donald W. Hyndman

2000 *Roadside Geology of Northern and Central California*. Missoula, Montana: Mountain Press Publishing Company.

Alvarez, Susan Harding, and David A. Fredrickson

1989 Cultural Resources Inventory, Sonoma Coast State Beach from Goat Rock to Bodega Head, Sonoma County, California. Report prepared for California State Parks by Anthropological Studies Center, Sonoma State University. On file at Northwest Information Center, Sonoma State University, Rohnert Park, California.

Anonymous

1995 Clarification is sought regarding status of hair. *Mammoth Trumpet* 10(1):1.

1999 DNA sequences from times past in GenBank. *NCBI News*, Spring, p. 3.

Atwater, Brian F., Charles W. Hedel, and Edward J. Helley

1977 Late Quaternary Depositional History, Holocene Sea-Level Changes, and Vertical Crust Movement, Southern San Francisco Bay, California. *Geological Survey Professional Paper* 1014. Washington: United States Geological Survey.

Baker, Samuel White

1854 *Rifle and Hound in Ceylon*. London: Longman.

Barsness, Larry

1985 *Heads, Hides & Horns*. Fort Worth: Texas Christian University Press.

Beatty, Marvin T., and Robson Bonnichsen

1994 Dispersing aggregated soils and other fine earth in the field for discovery of organic archaeological materials. *Current Research in the Pleistocene* 11:73-74.

Benyus, Janine M.

1992 *Beastly Behaviors*. Reading, Massachusetts: Addison-Wesley Publishing Company. *Animals*. New York: Black Dog and Leventhal Publishers.

Bickel, Polly McW.

1978 Changing sea levels along the California coast: anthropological implications. *The Journal of California Anthropology* 5(1):6-20.

Birkeland, P.W.

1972 Late Quaternary eustatic sea-level changes along the Malibu Coast, Los Angeles County, California. *Journal of Geology* 80:432-448.

Bonnichsen, R., M.T. Beatty, M.D. Turner, and M. Stoneking

1996 What can be learned from hair? A hair record from the Mammoth Meadow Locus, southwestern Montana. In *Prehistoric Mongoloid Dispersions*, Takeru Akazawa and J.E. Szathmary, eds., pp. 201-213. Cambridge: Oxford University Press.

Bonnichsen, Robson, and C.W. Bolen

1985 On the interpretation of hair for Pleistocene studies. *Current Research in the Pleistocene* 3:63-64.

Bonnichsen, R., C.W. Bolen, M.D. Turner, J.C. Turner, and M.T. Beatty

1992 Hair from Mammoth Meadow II, southwestern Montana. *Current Research in the Pleistocene* 9:75-78.

Bonnichsen, Robson, Larry Hodges, Walter Ream, Katharine G. Field, Donna L. Kirner, Karen Selsor, and R.E. Taylor

2001 Methods for the study of ancient hair: radiocarbon dates and gene sequences from individual hairs. *Journal of Archaeological Science* 28(7):775-785.

Bourliere, Francois

1954 *The Natural History of Mammals*. New York: Alfred A. Knopf.

Bowen, Oliver E., Jr.

1951 Highways and Byways of Particular Geologic Interest. In *Geologic Guidebook of the San Francisco Bay Counties, Bulletin 154*, Olaf P. Jenkins (ed.), pp. 315-379. San Francisco.

Cahalane, Victor H.

1961 *Mammals of North America*. New York: The MacMillan Company.

Chaney, Ralph W.

1951 Prehistoric Forests of the San Francisco Bay Area. In *Geologic Guidebook of the San Francisco Bay Counties, Bulletin 154*, Olaf P. Jenkins (ed.), pp. 193-202. San Francisco.

Dary, David A.

1989 *The Buffalo Book*. Ohio University Press.

Davis, James T.

1961 Trade routes and economic exchange among the Indians of California. *University of California Archaeological Survey Report No. 54*.

Davis, O.K., L.D. Agenbroad, P.S. Martin, and J.I. Mead

1984 The Pleistocene dung blanket of Bechan Cave, Utah. *Carnegie Museum of Natural History Special Publication*: 267-282.

Davis, O.K., J.I. Mead, P.S. Martin, and L.D. Agenbroad

1985 Riparian plants were a major component of the diet of mammoths of southern Utah. *Current Research in the Pleistocene* 2:81-82.

Demirpolat, S.

1991 Surface and near-surface sediments from the continental-shelf off the Russian River, northern California. *Marine Geology* 99(1-2):163-173.

Edwards, Stephen W.

1990 Observations on the prehistory and ecology of grazing in California. *Fremontia* 20(1):3-11.

Eisenberg, John F.

1971 "The elephant: life at the top." In *Animal Behavior*, Thomas B. Allen (ed.), pp. 190-207. Washington: National Geographic Society.

Elms, Ernest H.

1986 *Animals of the Western Rangeland*. Happy Camp, California: Naturegraph Publishers.

Eltringham, S.K.

1982 *Elephants*. Poole, U.K.: Blandford Press.

Estes, Richard Despard

1991 *The Behavior Guide to African Mammals*. Berkeley: The University of California Press.

Fredrickson, David A.

1962 Archaeological Investigations within Construction Site Area of Unit No. 1 of Pacific Gas and Electric Company's Atomic Park, Sonoma County, California. A report prepared for Western Heritage, Inc.

1984 The North Coastal Region. In *California Archaeology*, by Michael J. Moratto, pp. 471-528. Orlando: Academic Press.

Freeman, Dan

1979 *Elephants: The Vanishing Giants*. New York: G.P. Putnam's Sons.

Gobetz, Katrina E., and Steven R. Bozarth

2001 Implications for late Pleistocene mastodon diet from opal phytoliths in tooth calculus. *Quaternary Research* 55(2):115-122.

Grace, Eric S.

1993 *Elephants*. San Francisco: Sierra Club Books.

Grant, Chapman

1948 The "polished rocks" of Cornudas Mountain, New Mexico. *Science* (New Series), Vol. 107, No. 2773 (20 February 1948), pp. 191-192.

Grant, W.D., R.T. Gemmell, and T.J. McGenity

1998 Halobacteria: the evidence for longevity. *Extremophiles* 2(3):279-287.

Groning, Karl, and Martin Saller

1998 *Elephants: A Cultural and Natural History*. Cologne: Konemann.

Guthrie, R. Dale

1992 *Frozen Fauna of the Mammoth Steppe*. Chicago: The University of Chicago Press.

Hall, Don Alan

1999 Alberta scientists track mammoths across recently exposed landscape. *Mammoth Trumpet* 14(4).

Hansen, R.M.

1980 Late Pleistocene plant fragments in the dung of herbivores at Cowboy Cave. *University of Utah Anthropological Papers* 104, pp. 179-189.

Harris, John M., and George T. Jefferson

1984 *Treasures of the Tar Pits*. Los Angeles: Natural History Museum of Los Angeles County.

Haynes, Gary

1991 *Mammoths, Mastodons, & Elephants: Biology, Behavior, and the Fossil Record*. Cambridge University Press.

Higgins, C.G.

1952 Lower Course of the Russian River, California. *University of California Publication of the Department of Geological Sciences Bulletin* 29:181-264.

Hofreiter, M., H.N. Poinar, W.G. Spaulding, K. Bauer, P.S. Martin, G. Possnert, and S. Pääbo

1999 A molecular analysis of ground sloth diet through the last glaciation, *Molecular Ecology* 9, 1975-1984.

Hofreiter, Michael, David Serre, Hendrik N. Poinar, Melanie Kuch, and Svante Pääbo

2000 Ancient DNA. *Nature Reviews Genetics* 2(5):353-359.

Hopkins, D.M.

1967 *Quaternary Marine Transgression in Alaska: in the Bearing Land Bridge*. Stanford University.

Howard, Arthur D.

1951 Development of the Landscape of the San Francisco Bay Counties. In *Geologic Guidebook of the San Francisco Bay Counties*, O.P. Jenkins (ed.), pp. 95-106. *California Division of Mines Bulletin* 154.

1979 *Geologic History of Middle California*. Berkeley: University of California Press.

Iwago, Mitsuaki

1996 *Serengeti: Natural Order on the African Plain*. San Francisco: Chronicle Books.

1998 *Wildlife*. San Francisco: Chronicle Books.

Jackson, Peter

1990 *Elephants*. Secaucus, New Jersey: Chartwell Books.

Jefferson, George T.

1988 Late Pleistocene large mammalian herbivores: implications for early human hunting patterns in southern California. *Bulletin of the Southern California Academy of Sciences* 87(3):89-103.

1991 A Catalogue of Late Quaternary Vertebrates from California: Part Two, Mammals. *Technical Reports Number 7*. Los Angeles: Natural History Museum of Los Angeles County.

Jefferson, George T., and Judith L. Goldin

1989 Seasonal migration of *Bison antiquus* from Rancho La Brea, California. *Quaternary Research* 31:107-112.

Johnson, D.L.

1977a The California Ice-age refugium and the Rancholabrean extinction problem. *Quaternary Research* 8:149-153.

1977b The late Quaternary climate of central California: Evidence for an Ice Age refugium. *Quaternary Research* 8:154-179.

Jones, Martin

2001 *The Molecule Hunt: Archaeology and the Search for Ancient DNA*. New York: Arcade Publishing.

Kurtén, Björn, and Elaine Anderson

1980 *Pleistocene Mammals of North America*. New York: Columbia University Press.

Lang, Walter B.

1941 Polished areas on granitic porphyries of the Hueco and Cornudas Mountains of Texas and New Mexico. *Science* (New Series), Vol. 94, No. 2443 (24 October 1941), pp. 390-391.

1947 The polished rocks of Cornudas Mountain, New Mexico. *Science* (New Series), Vol. 105, No. 2716 (17 January 1947), p. 65.

Laury, Robert L.

1994 Paleoenvironment of the Hot Springs Mammoth Site. In *The Hot Springs Mammoth Site*, Larry D. Agenbroad and Jim I. Mead, eds., pp. 28-67. Hot Springs, South Dakota: The Mammoth Site of South Dakota.

Lea, Peter D.

1997 Vertebrate tracks in Pleistocene eolian sand-sheet deposits of Alaska. *Quaternary Research* 45(2):226-240.

Letey, John, ed.

1986 *Soil and Plant Interactions with Salinity. Kearney Foundation Five-Year Report, 1980-1985.* Agricultural Experiment Station, University of California, Division of Agriculture and Natural Resources.

Lindahl, Tomas

1997 Facts and artifacts of ancient DNA. *Cell* 90:1-3.

Lipps, Jere H., and Eldridge M. Moores

1971 *Geologic Guide to the Northern Coast Ranges, Point Reyes Region, California.* Annual Field Trip Guidebook of the Geological Society of Sacramento.

Lister, Adrian, and Paul Bahn

1994 *Mammoths.* New York: MacMillan.

Lockley, Martin, and Adrian P. Hunt

1995 *Dinosaur Tracks and Other Fossil Footprints of the Western United States.* New York: Columbia University Press.

Loy, Thomas H., and E. James Dixon

1998 Blood residues on fluted points from eastern Alaska. *American Antiquity* 63(1):21-46.

Lundelius, Ernest L., Jr., and Russell Graham

1999 The weather changed: Shifting climate dissolved ancient animal alliances. *Discovering Archaeology* 1(5):48-51, 53.

MacClintock, Dorcas

1976 *A Natural History of Zebras.* New York: Charles Scribner's Sons.

MacPhee, Ross D.E., and Preston A. Marx

1997 The 40,000-year plague: Humans, hyperdisease, and first-contact extinctions. In *Natural Change and Human Impact in Madagascar*, S.M. Goodman and B.D. Patterson, eds., pp. 169-217. Washington: Smithsonian Institution Press.

1999 Mammoths & microbes: Hyperdisease attacked the New World. *Discovering Archaeology* 1(5):54-56, 59.

Martin, Paul

1967 Prehistoric overkill. In *Pleistocene Extinctions: The Search for a Cause*, P.S. Martin and H.E. Wright, eds., pp. 75-120. New Haven: Yale University Press.

1999 The time of the hunters: A "blitzkrieg" by fierce humans killed off the giants. *Discovering Archaeology* 1(5):40-41, 43-45, 47.

Martin, P.S., and R.G. Klein, eds.

1984 *Quaternary Extinctions: A Prehistoric Revolution.* Tucson: University of Arizona Press.

Mason, H.L.

1934 Pleistocene flora of the Tomales Formation. *Carnegie Institute Washington Publication* 415:81-179.

McCluskey, Kevin

2001 Beyond Jurassic Park: real science with ancient DNA. *Plant Health Progress* (19 October 2000).

McHugh, Tom

1972 *The Time of the Buffalo*. New York: Alfred A. Knopf.

Mead, J.I., L.D. Agenbroad, P.S. Martin, and O.K. Davis

1985 Dung of *Mammuthus* in the arid Southwest, North America. *Quaternary Research* 25:121-127.

Miller, V.C.

1972 Soil Survey of Sonoma County, California. United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station.

Milliman, J.D., and K.O. Emery

1968 Sea levels during the past 35,000 years. *Science* (New Series) Vol.162, pp.1121-1123.

Minard, Claude R., Jr.

1971 Quaternary Beaches and Coasts between the Russian River and Drakes Bay, California. University of California, Hydraulic Engineering Laboratory, Berkeley.

Mol, Dick, and Larry D. Agenbroad

1994 Metapodials and shoulder height of *Mammuthus columbi* compared with Eurasian *Mammuthus* Species. In *The Hot Springs mammoth Site*, Larry D. Agenbroad and Jim I. Mead (eds.), pp. 224-252. Hot Springs, South Dakota: The Mammoth Site of South of South Dakota.

Mol, Dick, Larry D. Agenbroad, and Jim I. Mead

1993 *Mammoths*. Hot Springs, South Dakota: The Mammoth Site of South Dakota.

Monaghan, Jay

1963 *The Book of the American West*. New York: Julian Messner.

Moratto, Michael J.

1984 *California Archaeology*. Orlando: Academic Press.

Norberg, Bob

2002 Unlocking the Past: Sonoma County Landmark May Reveal Mastodon, Mammoth Habits. *The Press Democrat*, Saturday, April 27, 2002, pp. B1, B3. Santa Rosa, California.

Norris, Robert M., and Robert W. Webb

1990 *Geology of California*. 2nd edition. New York: John Wiley & Sons.

Ouzman, Sven

1996a Thaba Stone: place of rhinoceroses and rain-making. *African Studies* 55:31-59.

1996b An engraved touchstone from the Free State. *The Digging Stick* 13(3):1-3.

2001 Seeing is deceiving: rock art and the non-visual. Archaeology and aesthetics. *World Archaeology* 33(2):237-256.

Owen, Denis

1981 *Grasslands of Africa*. New York: The Audubon Society.

Pääbo, Svante

1986 Molecular cloning of ancient Egyptian mummy DNA, *Nature* 314(6012):644-645.

Poinar, Hendrick N., Michael Hofreiter, W. Geoffrey Spaulding, Paul S. Martin, B. Artur Stankiewicz, Helen Bland, Richard P. Evershed, Göran Possnert, and Svante Pääbo

1998 Molecular coproscopy: dung and diet of the extinct ground sloth *Nothrotheriops shastensis*, *Science*, Volume 281, Number 5375 (17 July 1998), pp. 402-406.

Poinar, Hendrick N., Matthias Höss, Jeffrey L. Bada, and Svante Pääbo

1998 Amino acid racemization and the preservation of ancient DNA. *Science*, Vol. 272, Issue 5263, pp. 864-866.

Poinar, George, and Roberta Poinar

1995 *The Quest for Life in Amber*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Prentice, C.S.

1989 Earthquake Geology of the Northern San Andreas Fault Near Point Arena, California. Unpublished doctoral dissertation, California Institute of Technology, Pasadena, California.

Pusch, Carsten M., Ian Giddings, and Michael Scholz

1999 Repair of degraded duplex DNA from prehistoric samples using *Escherichia coli* DNA polymerase I and T4 DNA ligase, *Nucleic Acids Research* 26(3):857-859.

Ream, Walt, Orin C. Shanks, and Robson Bonnicksen

1999 Ancient DNA from Overlooked Sources: Stone Tools and Hair. Paper presented at the Clovis and Beyond Conference, October 28-31, Santa Fe, New Mexico.

Rue, Leonard Lee, III

1997 *The Deer of North America*. New York: Lyons & Burford, Publishers.

2000 *Way of the Whitetail*. Stillwater, Minnesota: Voyageur Press.

Russell, Emily W. B.

1982 Pollen analysis of past vegetation at Point Reyes National Seashore, California. *Madrono* 30(1):1-11.

Rypins, Steven, Steven L. Reneau, Roger Byrne, and David R. Montgomery

1990 Palynologic and geomorphic evidence for environmental change during the Pleistocene-Holocene transition at Point Reyes Peninsula, Central Coastal California. *Quaternary Research* 32: 72-87.

Saiki, R.K., D.H. Gelfand, S. Stoffel, S.J. Scharf, R. Higuchi, G.T. Horn, K.B. Mullis, and H.A. Erlich

1987 Primer-directed enzymatic amplification of DNA with a thermostable DNA polymerase, *Science* 239(4839):487-491.

Sample, Michael S.

1987 *Bison: Symbol of the American West*. Billings, Montana: Falcon Press.

Savage, D.E.

1951 Late Cenozoic vertebrates of the San Francisco Bay Region. *University of California Publication of the Department of Geological Sciences Bulletin* 28:215-314.

Schwaderer, Rae

1992 Archaeological test excavation at the Duncans Point Cave, CA-SON-348/H. In *Essays on the Prehistory of Maritime California*, pp. 55-71, Terry L. Jones (ed.), Center for Archaeological Research at Davis, Publication Number 10.

Shainberg, I., and John Letey

1984 Response of soils to sodic and saline conditions. *Hilgardia* 52:1-57.

Simons, Dwight D., Thomas N. Layton, and Ruthann Knudson

1985 A fluted point from the Mendocino County Coast, California. *Journal of California and Great Basin Anthropology* 7(2):260-269.

Skead, J.K.

1976 The mystery of the rubbing stones. *African Wildlife* 30(3):21, 25.

Sloan, Doris

2001 Goat Rock State Beach: rising land and crashing waves on the Sonoma Coast. *Bay Nature* 1(3):8-9, 22-23.

Smithers, R.S.

1983 *The Mammals of the Southern African Subregion*. Pretoria.

Stirton, R.A.

1951 Prehistoric Land Animals of the San Francisco Bay Region. In *Geologic Guidebook of the San Francisco Bay Counties, Bulletin 154*, Olaf P. Jenkins (ed.), pp. 177-186. San Francisco.

Stock, Chester

1956 *Rancho La Brea: A Record of Pleistocene Life in California*. Los Angeles County Museum.

Stone, Richard

2002 *Mammoth*. Cambridge, Massachusetts: Perseus Publishing.

Storer, Tracey L., and Lloyd P. Tevis, Jr.

1955 *California Grizzly*. Lincoln: University of Nebraska Press.

Taylor, P.E. Hare, C.A. Prior, D.L. Kirner, L. Wan, and R.B. Burky

1996 Radiocarbon dating of biochemically characterized hair. *Radiocarbon* 37:1-11.

Thompson, Thomas H., & Co.

1877 *Historical Atlas Map of Sonoma County, California*. Oakland: Thomas H. Thompson & Co.

Vreeland, R.H., A.F. Piselli, Jr., S. McDonnough, and S.S. Meyers

1998 Distribution and diversity of halophilic bacteria in a subsurface salt formation. *Extremophiles* 2(3):321-331.

Wagner, D.L., and E.J. Bortugno

1981 Geologic Map of the Santa Rosa Quadrangle, California, 1:250,000. Sacramento: California Division of Mines and Geology.

Wilson, M.R., D. Polanskey, J. Butler, J.A. Dizinno, and B. Budowle

1994 Extraction, PCR amplification and sequencing of mitochondrial DNA from human hair shafts. *BioTechniques* 18:662-669.

Wright, Terry

1996 Shell Beach: A Close Look at a Subduction Zone. Unpublished paper available on the Internet.

¹ This paper was written on August 27, 2002 and revised on October 28 of that same year.

² Raj Naidu, a local paleontologist, was the co-discoverer of these features along with the author.

³ CA-SON-348/H has been dated to 8,000 B.P., but the site appears to be considerably older than that. It likely contains a Paleoamerican component.

⁴ In 1972, James West, then with the University of California Museum of Paleontology at Berkeley, salvaged a mammoth tusk and lower jaw with a tooth from an eroding area near Bodega Head.

⁵ This site, discovered by Raj Naidu in 1991, consists of tree remains including small cones. In July of this year, Michael Kennedy and the author collected a sample of wood from the site. We are currently awaiting an AMS date on it from the Lawrence Livermore Lab. The date will help us determine the age of the marine terrace at Bodega Head. A second site, as yet unrecorded, has recently been discovered by Kennedy elsewhere at Bodega Head. This site consists of fossil conifer logs protruding several feet out of a deeply buried deposit in the cliff face. A third site, consisting of

large, fossil conifer logs, was identified by David Fredrickson at nearby Campbell Cove in the early 1960s (Fredrickson 1962:80-81). Fossil conifer deposits are also known from nearby Tomales Bay, where they have been dated at about 30,000 B.P.

⁶ The name, "Mammoth Rocks," reflects the behemoth size of the rockstacks rather than the author's hypothesis that the rubs were created by mammoths. The rocks comprising Locus 1 are also referred to as "Sunset Rocks" by local climbers.

⁷ "Pleistocene Park" is a 160 km² experimental wildlife preserve associated with the Northeast Science Station, Cherskii, Russia. The Station is located 150 km south of the Arctic Ocean on the mouth of the Kolyma River, in northeastern Siberia (Yakutia). It was founded by a group of scientists in 1989, and is today the scene of international research. The Station's Director, Dr. Sergei Zimov, is the leading proponent of Pleistocene Park.

⁸ The results of a recent Internet search indicate that rubbing stones are found at these sites on the Northern Plains: Nose Hill and Fish Creek Parks in Calgary, Alberta; Big Rock near Okotoks, Alberta; Hanna Museum in Hanna, Alberta; River Park Farm on the Souris River in Manitoba; Living Prairie Museum at Winnipeg, Manitoba; Grasslands National Park near Moose Jaw in Saskatchewan; Coal Mine Ravine near Herschel in Saskatchewan; Last Mountain Lake National Wildlife Area in Saskatchewan; Saskatchewan Landing Provincial Park near Swift Current, Saskatchewan; Wanuskewin Heritage Centre in Saskatoon, Saskatchewan; Buffalo Rubbing Stone Provincial Park in Saskatchewan; Stump Lake National Wildlife Refuge, North Dakota; and Pankratz Memorial Prairie near Crookston, Minnesota. Another rubbing stone is located between Youngstown and Kindersley, Saskatchewan, and is marked as a highway "point of interest." These fifteen occurrences probably represent but a small fraction of the bison rubbing stones known to occur on the Northern Plains.

⁹ In Australia's Kakadu National Park, feral water buffalo have impacted Aboriginal cave paintings in the same manner.

¹⁰ Mammoth remains have been found in Santa Rosa, Glen Ellen, Valley Ford, Graton, and on the Estero de San Antonio near Bodega Bay.

¹¹ Ancient DNA was extracted from fossil sloth (*Nothrotheriops shastensis*) dung recovered from Gypsum Cave, and used to reconstruct not only the animals' diet, but the late Pleistocene environment as well (Poinar *et al.* 1998; Hofreiter *et al.* 2000).

¹² I have inspected several of the Canadian rubbing rocks. Their rubbed surfaces are similar in appearance to the rubbing rocks found on the Sonoma Coast.

¹³ Whereas the mastodon is generally considered to have been a browser, recent studies suggest that grasses were very important to its diet as well (Gobet and Bozarth 2001).

¹⁴ None of the Holocene's native animals, such as deer and elk, are thought to have created any of the rubs at Mammoth Rocks. While male deer are known to rub against saplings in order to leave a scent mark, there is no indication that they create rubs on rock like those found at the site.

¹⁵ Between 13,000-10,000 B.P., the mammoth, mastodon, camel, ancient bison, giant ground sloth, western horse, and many other Rancholabrean species vanished from North America. Three major theories have been offered to explain the extinctions. The first theory, the "Climate Hypothesis," explains the extinctions as a result of climatic change (Lundelius and Graham 1999). The second, known as the "Blitzkrieg Hypothesis," suggests that Paleoamerican hunting pressure resulted in the animals' demise (Johnson 1977a; Martin 1967, 1999; Martin and Klein 1984). The third, and newest theory, the "Hyperdisease Hypothesis," suggests that deadly diseases were the culprits of extinction (MacPhee and Marx 1997, 1999).

¹⁶ The rubs that are found at Mammoth Rocks can be ruled out as features created by rock climbers. The rubs cover many areas untouched by the climbers, and can be several meters in diameter. Because the rubs have weathered at a different rate than the rest of the rock, the edges of the rubs are sometimes raised. The climbers often use the raised edges as climbing and gripping platforms. The concern here is that the climbers will introduce their own polish along the edges of the rubs.

¹⁷ The concept of converting a portion of Sonoma Coast State Beach into a new "Pleistocene Park" is merely an idea raised herein by the author. At the present time, the State has no official plans for the Mammoth Rocks site, or the surrounding area, other than for the current use.