ARCHAEOLOGICAL RESEARCH ISSUES
FOR THE POINT REYES NATIONAL SEASHORE –
GOLDEN GATE NATIONAL RECREATION AREA

Prepared for the National Park Service Golden Gate National Recreation Area

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cover: Timing and Extent of Sea-level Rise in the San Francisco Bay Area
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FOR THE POINT REYES NATIONAL SEASHORE –
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for
Geoarchaeology
Indigenous Archaeology
Historical Archaeology
Maritime Archaeology

edited by
Suzanne Stewart and Adrian Praetzellis
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prepared for
National Park Service
Golden Gate National Recreation Area
San Francisco, California

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An Overview of Geoarchaeological Research Issues
by Jack Meyer

An Overview of Research Issues for Indigenous Archaeology
by Suzanne B. Stewart

An Overview of Research Issues for Historical Archaeology
by Annita Waghorn

An Overview of Research Issues for Maritime Resources
by Robert G. Douglass

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prepared for
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Golden Gate National Recreation Area
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Archeological Research Issues, Point Reyes National Seashore – Golden Gate National Recreation Area

Figure 1
Study Area and Vicinity

Key
- Point Reyes National Seashore
- Areas owned or administered by GGNRA

Source: NPS 1994
As a part of the Archaeological Overview and Assessment for the Point Reyes National Seashore and the Golden Gate National Recreation Area, under a cooperative agreement between Sonoma State University and the National Park Service, the Anthropological Studies Center (ASC) has produced several overviews of research issues—or general archaeological research designs—to aid in management of archaeological resources in the PRNS–GGNRA parklands. The geographic scope of the study area is relatively vast, extending over 108 miles of coastline—from northern Marin County in the north into northern San Mateo County in the south (Figure 1). These overviews are necessarily general, as they are intended for use with all known and anticipated archaeological resources in the PRNS and GGNRA, an area of approximately 182,496 acres, of which only 6,000 acres have been intensively surveyed. The presentation of research issues in these overviews will assist managers and archaeologists in developing specific research designs for individual properties or specific land units as the need arises. While these overviews are presented here as a single, edited volume, each is designed to be printed out separately as a standalone document if desired. Each overview is listed below, along with a general statement of the topic and the name and credentials of the author.

The first, An Overview of Research Issues for Geoarchaeology in the PRNS–GGNRA, is by ASC Staff Geoarchaeologist Jack Meyer (M.A. in Cultural Resources Management [CRM], Registered Professional Archaeologist [RPA]). It takes a geoarchaeological landscape approach that incorporates human ecology, landscape evolution, and soil formation. With a focus on landforms available to human beings in the past, including buried features, it offers a new perspective on the current archaeological database. Geoarchaeological research issues that can be addressed by parkland resources are provided, along with their data requirements.

An Overview of Research Issues for Indigenous Archaeology in the PRNS–GGNRA is by Suzanne B. Stewart, a Staff Archaeologist at the ASC (M.A. in CRM, RPA). The overview discusses the evolution of research designs for prehistoric archaeology in California, and reviews local research designs and their uses. It then describes and evaluates past indigenous (prehistoric and historic Native American) archaeological research on various topics—such as chronology, settlement, social organization, and culture change—offering a discussion of research issues and data requirements for each topic. The last section brings together the research issues and data requirements for all topics to aid in developing specific research designs. (The study for indigenous archaeology had a more ambitious scope of work than the other overviews, which were conducted under modifications to the original project statement—hence its greater size.)

An Overview of Research Issues for Historical Archaeology in the PRNS–GGNRA is by ASC Staff Archaeologist Annita Waghorn (M.A. in CRM, RPA). It describes the legal context for archaeological research and enumerates the property types that are known or anticipated in the study area. Research issues and data requirements are provided for selected research themes that pertain to Spanish-colonial/Mexican-period and American-period urban and rural archaeological resources. A review of property types and research efforts related to the dairy industry (a dominant theme in the late-19th and early-
20th century on the Point Reyes peninsula) is provided in an appendix prepared by Christina MacDonald, CRM graduate student and archaeological specialist at the ASC.

An Overview of Research Issues for Maritime Resources in the PRNS–GGNRA is by Robert G. Douglass (M.A. in CRM, RPA). This overview looks at the history of the study area as it relates to human interaction with the sea, and reviews the major archaeological studies that have been conducted over the years to increase our knowledge and understanding of these local maritime activities. In order to establish a context for research, it examines current general directions in maritime archaeology and presents some relevant examples of recent activities within the discipline. The overview also suggests an organizational framework for parkland maritime resources, consisting of a range of physical property types and historical contexts that can be combined to describe most maritime properties likely to be encountered in the GGNRA and PRNS. Finally, it proposes some research questions and areas for potential study, and makes specific recommendations for future treatment of the maritime properties of the parklands.

Maria Ribeiro, ASC specialist, provided editorial assistance and graphics and production expertise in organizing and producing this volume. Her skill and diligence are greatly appreciated.

Leo Barker, Park Archaeologist, Division of Cultural Resources and Museum Management, Golden Gate National Recreation Area, provided direction from the National Park Service.

Suzanne B. Stewart
ASC Staff Archaeologist

Adrian Praetzellis
ASC Director
PART I

AN OVERVIEW OF GEOARCHAEOLOGICAL RESEARCH ISSUES FOR THE PRNS - GGNRA

by

Jack Meyer, M.A., RPA
AN OVERVIEW OF GEOARCHAEOLOGICAL RESEARCH ISSUES

Jack Meyer

GEOENVIRONMENTAL SETTING

Recent studies indicate that prehistoric people probably utilized the California coast for the past 13,000 years or more (Johnson 2003:66; Rockwell 2003:67). During that time, the San Francisco Bay Area has undergone a series of significant large-scale environmental changes that influenced the pattern of human settlement and the nature and intensity of their subsistence activities. These changes have included substantial fluctuations in the distribution and availability of important natural resources, and widespread deposition of sediments that have buried large portions of once habitable landscapes. As a result, the region’s archaeological record cannot accurately reflect the timing or extent of human use, because landscape evolution has resulted in the submergence, destruction, and/or burial of many prehistoric archaeological deposits (Atwater 1979; Bickel 1978a, 1978b; Erlandson and Colten 1991).

Perhaps the most dramatic changes in the Bay Area landscape are related to sea-level rise. During the last glacial maximum, more than 15,000 years ago, worldwide sea levels were at least 100 meters (about 328 feet) lower than today (Bard et al. 1996). At that time, the broad sloping plain that forms the continental shelf was fully exposed, because the Pacific Ocean was located at least 10 kilometers (6.2 miles) west of the present PRNS-GGRNA shoreline (Figure I.1). Much of the area now occupied by the waters of San Francisco Bay was then a broad inland valley crossed by stream or river channels that supported grassland and riparian plant and animal communities. The runoff from these streams and rivers combined to form a single watercourse just north of Angel Island, which crossed the shelf before it emptied into the Pacific Ocean near the Farallon Islands (Atwater, Hedel, and Helley 1977) or perhaps just north of Cordell Bank. Lower sea levels promoted the southward transport of beach and dune sand along the coast, and the formation of alluvial and colluvial landforms on the continental shelf (Minard 1971).

As the continental ice sheets began to melt toward the end of the Pleistocene, the oceans of the world experienced a rapid rise in sea level, which caused the Pacific shoreline to migrate eastward. Between 15,000 and 11,000 years ago, sea levels rose about 55 m (180 ft.), at an average rate of about 13 m (42.6 ft.) every 1,000 years worldwide (Bard et al. 1996)—enough to cover most of the continental shelf, as shown in Figure I.2. This probably led to the formation of short-lived marshes and estuaries as sediments were trapped in the coastal valleys and embayments during the advance (Clifton, Hunter, and Gardner 1988:125).

By about 10,000 years ago, the rising sea passed through the Golden Gate and began to flood the inland area that would become San Francisco Bay (Atwater, Hedel, and Helley 1977). The lowest portions of the Bay valley were flooded as sea level rose about 25 m (82 ft.) between 11,000 and 8,000 years ago, at an average rate of about 8.3 m (27.2 ft.) every 1,000 years (Figure I.3). Coincidentally, the earliest known archaeological sites (CA-CCO-696 and CA-SON-348/H) in the region date to this time (Meyer and Rosenthal 1997;
Figure 1.1 Location and Submarine Features of the Continental Shelf West of the PRNS-GGNRA
Figure I.2. Timing and Extent of Sea-level Rise in the San Francisco Bay Area
Schwaderer 1992). Between about 8,000 and 6,000 years ago, sea-level rise rapidly decreased to only about 7 m (23 ft.) over 2,000 years, for an average rate of 3.5 m/1,000 years (Atwater 1979; Atwater, Hedel, and Helley 1977; Stanley and Warne 1994; Wells 1995; Wells and Goman 1994). During the past 6,000 years, sea level rose another 8 m (26.2 ft.), for an average rate of about 1.3 m (4.3 ft.) every 1,000 years (Figure I.3).

As the rate of sedimentation began to outpace the rate of submergence, tidal flats, marshes, and lagoons began to form around the margins of the Bay-Estuary (Atwater et al. 1979) and in many protected bays and inlets located along the Pacific coastline. The combination of higher sea levels, increased sedimentation, and wetland formation forced local streams and rivers to adjust to progressively higher baselines and lower hydrologic gradients. In response, many streams and rivers were overwhelmed by sediment that filled existing channels, formed new floodplains, and/or spread over the surface of existing floodplains (Helley et al. 1979). During this time, the upper reaches of some floodplains were subject to erosion and lateral channel migration as streams and rivers adjusted to the new conditions. These changes eventually led to the formation of an “alluvial apron around the bay plain and the extensive valleys of the region” (Helley et al. 1979:18) that is graded to the present sea level.

Geological and geoarchaeological studies demonstrate that many of the older land surfaces in the San Francisco Bay Area are overlain by younger deposits of alluvium, colluvium, dune sand, and/or artificial fill (Borchardt 1992; Helley et al. 1979; Knudsen et al. 2000; Mc Ilroy, Meyer, and Praetzellis 2001; Meyer 1996, 2000; Meyer and Rosenthal 1997; Pape 1978; Rogers 1988). The older land surfaces are often marked by buried soils (paleosols), which are indicative of prolonged periods of land stability. Buried soils have been identified in many of the floodplains and dunes around the Bay Area that have been radiocarbon-dated to less than 11,000 B.P. As such, buried paleosols are useful stratigraphic markers for locating buried archaeological deposits and aid in the correlation of depositional sequences in different areas (Meyer 2000).

During the Middle and Late Holocene, bays and estuaries expanded in response to a combination of higher sea levels and the decomposition, compaction, and subsidence of intertidal deposits (Atwater 1979; Atwater et al. 1979; Atwater, Hedel, and Helley 1977). This is particularly true in southern San Francisco Bay, where tectonic lowering, isostatic downwarping, and groundwater subsidence caused the Bay–Estuary deposits to expand at a greater rate than elsewhere within the Bay. Studies indicate that these deposits have subsided at a rate of about 1.0 mm/year since the onset of the Late Holocene, and that they currently occur as far south as at any time during the Holocene (Atwater, Hedel, and Helley 1977). By the 1850s the tidal marshes of the Bay covered twice as much surface area as all the inland water of the Bay and Delta combined (Atwater et al. 1979). Many portions of the shoreline have since been pushed back toward the Bay by artificial filling, levee construction, the deposition of hydraulic-mining debris, and other human activities (Peterson et al. 1995:60).

A series of significant paleoenvironmental changes have been detected through the isotopic, taxonomic, and radiometric analysis of sediments and of plant and animal remains in the Bay Area (Borchardt and Lienkaemper 1999; Byrne et al. 2001; Goman 1996; Goman and Wells 1999; Ingram 1998; Ingram and DePaolo 1993; Ingram, Ingle, and Conrad 1996a,
Figure I.3. Timing of Sea-level Rise Based on Calibrated Radiocarbon Dates from the San Francisco Bay Area. Note the age/depth of samples from Bolinas and Tomales Bay.
It appears that climatic conditions during the Early Holocene were drier and perhaps warmer than today based on the development of calcium-carbonate horizons in East Bay sediments dating between 10,000 and 7,000 years ago (Borchardt and Lienkaemper 1999:917). Several studies suggest that over the past 6,000 to 7,000 years, there were substantial fluctuations in salinity, sedimentation, water temperature, and marsh development in the Bay. Incipient marshes were periodically formed and drowned between 6,300 and 5,100 years ago, due to sedimentation rates that were “alternatively superseded” by the rate of sea-level rise (Wells 1995:193). By 5,700 years ago, oysters had established populations in the southern part of the Bay, just north of the San Mateo Bridge (Story, Wessels, and Wolfe 1966), coinciding with a period of low sedimentation rates in that area (Ingram, Ingle, and Conrad 1996b). Extensive deposits of peat, characteristic of stable marsh environments, formed around much of the Bay and Delta area about 6,000 to 4,000 years ago, when many of the earlier sites around the Bay also first appeared.

Isotopic analysis of diatoms, pollen, and shellfish reveals that freshwater inflows (high runoff) into the Bay alternated with episodes of increased salinity (low runoff) during the Middle and Late Holocene (Byrne et al. 2001; Goman 1996; Well and Goman 1994; Ingram, Ingle, and Conrad 1996a, 1996b). Evidence indicates that periods of higher temperatures and salinity levels coincide with a decline in oyster (*Ostrea luridia*) and mussel (*Mytilus edulis*) populations, and a corresponding increase in the population of bent-nosed clams (*Macoma nasuta*), signaling a trend toward mud-dwelling species (Ingram 1998; Ingram, Ingle, and Conrad 1996a, 1996b). Between about 2,100 and 1,700 years ago, there was a significant increase in the rate of sedimentation that coincided with greater freshwater runoff and flourishing oyster populations in parts of the Bay. This was followed by a period of higher salinity levels and water temperatures between about 1,400 and 900 years ago, according to an analysis of small, bottom-dwelling protozoa (benthic *foraminifera*) from the south Bay (McGann 1995). It is likely that prehistoric human populations respond to periodic and perhaps critical shortfalls in the availability of certain species used for subsistence due to natural changes in the environment (Ingram 1998:108). Thus, natural fluctuations, rather than overexploitation, may explain the shift in relative abundance of shellfish species (oyster to clam) seen at many archaeological sites around the Bay (Bickel 1978a, 1978b; Gifford 1916; Greengo 1951; and Schenk 1926).

Although “the Quaternary vegetation history of coastal California is not well understood” (Adam, Byrne, and Luther 1981:255), fossil plant remains (pollen and macrofloral) indicate that significant climatic changes have occurred over the past 15,000 years. For instance, cypress, pine, and fir trees were far more common in the region during the Late Pleistocene, suggesting that conditions were cooler and/or wetter than today (Adam, Byrne, and Luther 1981; Rypins et al. 1989). These conditions supported the growth of a closed canopy forest dominated by pine and fir trees on the Point Reyes Peninsula (Rypins et al. 1989). A transition from pine/fir forests to grass/oak woodlands occurred during the Early and Middle Holocene, signaling a period of warmer and/or drier conditions in the region (West 1993, 2000). Evidence of this transition shows up at inland locations like Clear Lake in Lake County (Adams 1988; West 1993, 2000), and at coastal locations such as Point Reyes (Rypins et al. 1989) and Laguna de las Trancas in northern Santa Cruz County (Adam, Byrne, and Luther 1981). An increase in the number of Douglas

fir and redwood trees indicates that conditions became cooler and/or wetter during the Late Holocene, as found in the Clear Lake basin (West 1993) and at Pearson Pond in southeastern San Mateo County (Adam 1975).

The paleoclimatic sequence developed for the North Coast Ranges suggests that compared to the present-day climate, former climatic conditions (1) were more continental in the Late Pleistocene–Early Holocene; (2) were more Mediterranean in the Middle Holocene; and (3) have become more maritime in the Late Holocene (West 1993:232). These environmental changes likely correspond with certain landscape changes, as noted below.

Excluding tectonic activity, the genetic linkages of climate, vegetation, and geomorphic process should be most clearly evident during several phases marked by fluvial deposition separated by erosional hiatuses in the Clear Lake terrestrial deposits. The step-like transition from the Pleistocene to the Holocene should be evident in a number of landforms due to changes in the fluvial regime. A second transition in geomorphic processes should be evident beginning about 6000-7000 years ago. Landform processes should have stabilized to their current conditions some 2000-3000 years ago. Undoubtedly historic land-use patterns have altered these genetic linkages [West 2000:111].

More recent environmental changes in the region include widespread erosion of the uplands, rapid sediment deposition in the lowlands, the formation of deeply incised channels in alluvium-filled valleys, and the appearance of introduced (non-native) plant species. These changes, which generally coincide with the arrival of the Spanish and other Euro-American settlers during the 1700s and 1800s (West 1989), have been documented in part by pollen studies at the Presidio in San Francisco (Reidy 2001), on the Point Reyes peninsula (Duncan 1992; Mudie and Byrne 1980; Russell 1983), and at other locations in Marin County (Duncan 1992). During the late 1800s, protective vegetation cover was greatly reduced by intense drought and livestock grazing, which made the landscape particularly susceptible to erosion (Burcham 1957:171), as did many historic logging, mining, and agricultural practices. Lasting evidence of these changes is found along many stream and river channels, where the lower terraces are often composed of historic-age sediments (Knudsen et al. 2000), as are many of the estuarine deposits (Mudie and Byrne 1980).

GEARCHAEOLICAL LANDSCAPE APPROACH FOR THE PRNS–GGNRA

Geological and archaeological studies are unified by the principles of uniformitarianism and stratigraphic succession. Uniformitarianism is the view that processes operating at the present have operated the same way in the past to produce similar results, even though the processes may not have operated at the same rate or intensity. The uniformitarian principle is a central part of geocological reasoning, providing a basis for understanding the nature of past processes. The principle of superposition is derived from the observation that geological deposits often exhibit
sequential layers in which upper layers are younger than lower ones (excluding structural reversals or inversion). Stratigraphy is essential for establishing the spatial and temporal relationships between soils, sediments, and landforms as part of geoarchaeological studies (Waters 1992).

A geoarchaeological landscape approach is one that incorporates aspects of human ecology, landscape evolution, and soil formation. This approach is defined as “the archaeological investigation of past land-use by means of a landscape perspective, combined with the conscious incorporation of regional geomorphology, actualistic studies (taphonomy, formation processes, ethnoarchaeology) and marked by ongoing reevaluation and innovation of concepts, methods, and theory” (Rossignol 1992:4). The methods and application of a landscape approach are linked to general theory by uniformitarian assumptions and specific questions regarding observed changes in human land-use and social organization in the past. The ultimate goal of a landscape approach is to understand human social and economic change within the framework of an inclusive environmental and evolutionary context (Rossignol 1992:14). The application of a geoarchaeological landscape approach requires a detailed understanding of the natural geomorphic processes responsible for the formation of the present landscape. To accomplish this, the age and distribution of soils, sediments, and landforms are identified and evaluated in terms of human land use and occupation.

Landforms and geological processes are known to be significant factors in regulating the structure and function of ecosystems, which control the flow of materials and energy across a landscape (Stafford 1995:76). The distribution, organization, and interrelationships of people are likewise configured by these factors. At any one time, the landscape is composed of different deposits, soils, and landforms of various ages. This physical platform on which people interact with their environment is the geomorphic landscape (Waters 1992:88). The connection between human occupation and landscape evolution is simply that human activities have been, and still are, primarily associated with stable landforms. The likelihood that a landform will be used or occupied by people depends in large part on the duration of landform stability. Since evidence of past human alteration and/or occupation of a landscape is subject to the same processes that affect the preservation, distribution, and visibility of the noncultural deposits (Bettis 1992:119), the depositional history and subsequent evolution of a landscape ultimately determine whether archaeological remains will be preserved, destroyed, or redeposited (Kuehn 1993; Waters 1992).

There is an important distinction between soils and sediments. Sediment consists of particles that have been transported and deposited by geological processes, while soil is formed by the in-place alteration of rock and sediments over prolonged periods. The process of soil formation involves the addition, transformation, transfer, and removal of materials and chemicals in the soil as determined by the factors of climate, organisms, relief, parent material, and time (Holliday 1990). The combined effect of these factors at or near the surface results in the formation of subsurface horizons that become more distinct or well developed with time. Weakly developed soils have little or no horizon development and tend to be associated with young and/or unstable landforms. Well-developed soils have distinct horizons and tend to be associated with older, more stable landscapes. When erosion removes the surface of a landform, the process of soil formation
is resumed on the newly exposed surface. In the case where the surface of a landform is buried by a thick deposit of sediment, soil formation is stopped on the buried land surface, and resumes on the newly deposited surface. The age and nature of soils and sediments are particularly useful for assessing the archaeological sensitivity of an area because soil formation indicates that a landform was stable enough for human use.

A paleosol is an “old soil” that formed during a prolonged period of near-surface weathering on a relatively stable land surface in the past, but is not actively forming at the present (Retallack 1988; Waters 1992; Yaalon 1971). The recognition of paleosols is crucial for geoarchaeological studies because they represent relatively stable land surfaces that were potentially available for human use or occupation. A paleosol may represent hundreds or thousands of years of non-deposition and soil development, depending on the intensity and duration of landform stability. Once buried, paleosols can be used as stratigraphic markers (Holliday 1990). A number of publications provide more detailed discussions of the use and interpretation of soils, sediments, and paleosols in archaeology (Bettis 1995; Holliday 1990, 1992; and Waters 1992).

A buried site refers to any concentration of archaeological remains that is concealed from view by overlying natural or artificial deposits and/or by built structures, while a submerged site is any concentration of archaeological remains that is covered primarily by water. Because buried sites generally lack visible and/or obtrusive features that would otherwise indicate their presence to an observer in the field, the use of pedestrian survey methods is often inefficient or completely ineffective for locating such archaeological sites (Bettis 1992:120). Surveys that are designed to locate and estimate the potential of buried sites must rely on other methods and exploratory techniques to avoid the sampling biases introduced by conventional surface surveys.

LANDSCAPE EVOLUTION AND ARCHAEOLOGICAL SENSITIVITY IN THE PRNS–GGNRA

Archaeological sensitivity can be conceptualized as a set of factors that either encouraged or discouraged human use or occupation of certain landforms, combined with those that affected the subsequent preservation of archaeological remains associated with certain landforms. Given that prehistoric settlements in the PRNS–GGNRA are generally associated with relatively level landforms located along the coast or near active waterways, the present and former positions of coastlines and channels are useful for determining the possible site locations. The deposition of sediments has probably resulted in the burial of sites that may have been located in low-lying areas located along the coasts or waterways. Furthermore, artificial cutting and filling can also result in the destruction or preservation of archaeological sites. While it is impossible to predict the exact location of every site that may be buried, it is possible to identify archaeologically sensitive areas based on a combination of human settlement patterns and favorable geologic settings.

The PRNS–GGNRA area has a long and complex natural history that has produced a highly varied assemblage of geological deposits and landforms. The area lies within a portion of the California Coast Ranges that straddles the tectonically active San Andreas
Fault zone, which separates the North American (east) plate from the Pacific (west) plate. Over the past 11 million years, there has been as much as 150 km (94 miles) of right-lateral displacement of the geological deposits located along different segments of the fault (Clark and Brabb 1997:1). PRNS–GGNRA is underlain by a combination of igneous, metamorphic, and sedimentary bedrock that range in age from Jurassic to middle Pleistocene. Some Pleistocene-age marine deposits have been uplifted landward by tectonic activity, creating a series of benches or terraces along some segments of the Pacific coastline (Sowers, Noller, and Lettis 1998). The processes that formed these deposits generally occurred more than 20,000 years ago, or well before people first entered the region.

Many of the low-lying areas (i.e., basins, hollows, ravines, valleys, etc.) within the PRNS–GGNRA contain landforms that were formed during the past 15,000 years or less, such as fans, floodplains, terraces, and/or dunes. It is these depositional landforms that have the greatest potential of containing buried archaeological remains, given that people have occupied the region for at least 9,000 years (Meyer and Rosenthal 1997; Schwaderer 1992). The following sections (1) describe the timing and extent of the climatic and geomorphic processes that formed the landscape, (2) interpret how landscape changes may have affected human land use and occupation, (3) assess the nature and completeness of the archaeological record in different parts of the PRNS-GGNRA, and (4) briefly evaluate the archaeological sensitivity of certain landforms.

Offshore Landforms and Submerged Sites

Large segments of the PRNS–GGNRA are situated along the coastline of the Pacific Ocean and San Francisco Bay. As described above, rising sea levels submerged the continental shelf and led to the formation of bays and estuaries during the past 15,000 years. It also appears that some of these areas were submerged quite recently due to earthquake-induced subsidence along the San Andreas Fault (Knudsen et al. 1999b). Thus, prior to sea-level rise, large portions of the continental shelf were available for human use or occupation during the Late Pleistocene and part of the Early Holocene. As a result, there is “an excellent probability that components of these previous habitations may remain covered, by sediment and sea, and may be identifiable by archaeologists” (Terrell 2003:432), and that some of these remains are presently submerged in portions of the PRNS–GGNRA.

The continental shelf that lies west of PRNS-GGNRA beneath the waters of the Pacific is a broad, gently sloping surface that extends some 25 to 50 km (25 to 50 mi.) from the present shoreline to a depth of about 120 m (394 ft.) below mean sea level (Figure I.1). This is the broadest portion of the continental shelf along the California coast. The relatively flat surface of the shelf was created as worldwide sea levels advanced and retreated multiple times before attaining the present level. During low stands of the sea, a large river channel probably crossed the shelf from the Golden Gate to the shelf slope (Dean and Gardner 1995:1). It also seems likely that smaller channels cut by the larger coastal streams, such as Bolinas, Lagunitas, and Olema creeks, also crossed the shelf. Although it is not yet known if such channels exist, recent studies have found numerous topographic lows that form east to west “linear depressions” across the shelf (Chin, Karl, and Maher 1996), which may represent buried canyons, valleys, and/or channels.

Most of the shelf’s surface is covered with 1 to 2 m of unconsolidated sediments (gravel, sand, silt, clay, and shell) that are generally thought to have been deposited during
the Holocene (Chin, Karl, and Maher 1996; Karl 2001; Welday and Williams 1975). These sediments are at least 2 to 5 m thick adjacent to the Point Reyes headland and southwest of the Golden Gate, both west of the PRNS–GGNRA (Chin, Karl, and Maher 1996:267). Given that some of these deposits appear to contain buried channels (Chin, Karl, and Maher 1996; Cooper 1971:44), it is possible that some of the deposits are Pleistocene in age and not marine in origin. One former valley (that of Bolinas Creek) appears to be submerged along part of the San Andreas Fault zone that stretches from Bolinas Lagoon to just west of San Francisco (Cooper 1971:45-46). A radiocarbon date of 8400 ± 100 B.P. (9450 cal B.P.) obtained from sediments in Bolinas Lagoon at a depth of about 43 m (141 ft.; (Bergquist 1978) indicates that the valley fill is at least Early Holocene in age. The sea-floor sediments are underlain by an extensive unconformity (Chin, Karl, and Maher 1996; Field, Gardner, and Prior 1999) that represents an eroded (wave-cut) bedrock surface and, possibly, preserved remnants of Late Pleistocene-age soils and other terrestrial deposits. Evidence of a submerged “pre-transgressive” surface has been documented throughout Tomales Bay (Daetwyler 1965, 1966, see Figure I.4), and similar surfaces have been detected by side-scanning sonar and seismic reflection profiles in the offshore areas of the PRNS–GGNRA (Chin, Karl, and Maher 1996; Cooper 1971).

Evidence of submerged shorelines and/or dune deposits has been identified at certain locations on the continental shelf. Near Point Reyes, a large lobe of coarse sand extends more than 10 miles south of Drakes Bay, at depths of about 45 to 65 m (147 to 213 ft.) bmsl (Welday and Williams 1975). Because the texture of the sand lobe is too coarse to have formed under present conditions, the deposit is probably a relic of an older (Pleistocene?) beach (dune?) or near-shore deposit (Cherry 1965:75; Karl 2001; Minard 1964:35; Welday and Williams 1975). If so, then the deposits would have formed sometime between 13,000 and 11,000 years ago, based on the depth of the sand lobe and the estimated rate of sea-level rise. Other smaller remnants of former beaches are scattered along the coast at depths of about 18.3 m (60 ft.) bmsl, which probably represent the position of the shoreline around 9,000 years ago (Figure I.3). Coarse sediment similar to this is also found on portions of the shelf west of the Golden Gate, which “may reflect relict sediment from a low-stand deposit or a winnowed lag of San Joaquin-Sacramento River sediment” (Dean and Gardner 1995:3).

Former land surfaces have been identified beneath the waters of San Francisco Bay that represent the floor of the valley or floodplain that existed prior to the filling of the Bay. These deposits occur at depths ranging from 9.0 m to 40.0 m (29.5 ft. to 131 ft.) bmsl, which date between 10,920 and 9,760 cal B.P. (Atwater, Hedel, and Helley 1977; Story, Wessels, and Wolfe 1966). While no submerged Pleistocene- or Early Holocene-age archaeological sites have yet been discovered within the Bay, the remains of Pleistocene-age bison and mammoth have been found in association with buried landforms beneath the San Francisco–Oakland Bay Bridge (Rodda and Baghai 1993:1063). In the Fort Baker area of the GGNRA, a buried land surface dating to 1910 ± 70 B.P. (1860 cal B.P.) was identified beneath historic-age peat deposits at a depth of more than 3.8 m (12.4 ft.), within the former margin of Horseshoe Bay (Stewart, Meyer, and Newland 2003.). In the Presidio portion of the GGNRA, a series of buried soils formed in sand dunes was identified in cores obtained from the margins of a historic marsh that existed in the lower part of the base (Meyer 2002).
A. Schematic View of Tomales Valley/Bay Prior to Holocene Sea-Level Rise. Note the location of two possible submerged sites along the west side of the bay.


Figure 1.4. Tomales Bay before and after Sea-level Rise
At least a dozen submerged prehistoric archaeological deposits have been identified in and around the Bay Area. The basal portions of at least 10 prehistoric shell mounds were noted to occur below sea level, with some extending to depths of about 5.4 m (18 ft.) bmsl (Nelson 1909:330). In addition, two prehistoric human skeletons (CA-SFR-26 “Presidio skeleton” and CA-SFR-28 “BART skeleton”) have been recovered from estuary deposits around the former margins of the Bay. The BART skeleton, radiocarbon-dated to $4900 \pm 250$ B.P. (5640 cal B.P.), was found at a depth of more than 14 m (45 ft.) below the historic ground surface (23 m, or 75 ft., below the present surface) near the Civic Center on Market Street (Henn, Jackson, and Schlocker 1972; Henn and Schenk 1970). The Presidio skeleton, radiocarbon-dated to $1210 \pm 85$ B.P. (1145 cal B.P.), was found at a depth of more than 2.0 m (6.5 ft.) below surface at the Presidio in the PRNS-GGNRA (Moratto and Helgar 1973). Thus, at least one submerged site has already been identified within the PRNS-GGNRA.

Two other potentially submerged sites (the White Gulch Site and CA-MRN-249/H) have been identified along the west side of Tomales Bay. The White Gulch site (no trinomial yet assigned) is located in the White Gulch area along the west side of Tomales Bay, just west of Hog Island (Figure I.4). It was identified in 1964 when a shell bead, burned fish bones, and fragments of charcoal and shell were discovered in a core sample (Boring #1) recovered for a geological study (Daetwyler 1965, 1966; Follett 1968). These archaeological materials were recovered from depths of about 4.17 to 4.59 m (13.7 to 15 ft.) below mean sea level, and about 1.12 to 1.55 m (3.7 to 5.1 ft.) below the surface of the sediment on the bay bottom. Some of this material produced a radiocarbon date of $310 \pm 130$ B.P., or about 200 cal B.P., that “confirmed other evidence indicating very recent tectonic subsidence” (Follett 1968:1). Thus, this site may have been submerged due to tectonic activity and not as a result of Holocene sea-level rise.

MRN-249/H is located along the west shore of Tomales Bay across from the town of Marshall (Figure I.4). The site contains both historic and prehistoric archaeological materials, including human burials. During a field visit of the site in 1997, the remains of at least two fully articulated human skeletons were observed within the active tidal zone (Meyer 1997). These burials, separated by only a couple of meters, were remarkably well preserved and appeared to be associated with a black, weakly cemented sand deposit that contained a few heat-altered rocks and many fragments of marine shell. The condition of these remains and their location within the active tidal zone suggests that part of the site may have subsided as a result of relatively recent tectonic activity along the San Andreas Fault zone.

Paleoseismic studies indicate that parts of Bolinas Lagoon, Bodega Bay, and Tomales Bay underwent multiple episodes of rapid land subsidence and/or sea-level rise as a result of earthquake activity (Knudsen et al. 1999b). An abruptly buried soil horizon in estuarine sediment from northern Bolinas Lagoon provides evidence of an earthquake and sustained sea-level rise about 700 years ago. In the southeast part of Bodega Bay, rapid coseismic subsidence is indicated by three buried soils that occur within marsh deposits. Evidence of rapid sea-level rise is also found at the southern end of Tomales Bay. These investigations indicate that major earthquakes occurred along this portion of the San Andreas Fault about 700 years ago, and about 350 years ago (Knudsen et al. 1999b). The nature and timing of these seismic events suggests that some archaeological sites could have subsided or been submerged below sea level by tectonic activity in parts of the PRNS-GGNRA.
Figure 1.5. Distribution of Quaternary Geological Deposits in the Tomales Bay and Northern Point Reyes Area

(Adapted from Sowers, Noller, and Lettis 1998)
If prehistoric people inhabited portions of the continental shelf and lower valleys of the Bay Area during the Late Pleistocene and Early Holocene, they probably settled near protected coastlines and along active waterways, as they did during later periods. The eastward advance of the sea would have forced human populations to relocate their settlements farther inland. This would have been particularly true for the broad and gently sloping portions of the continental shelf west of San Francisco, which were affected quite early by sea-level rise (Bickel 1978a:7). Likewise, continued expansion of the Bay and other estuaries during the Middle and Late Holocene may have caused further movement of settlements to inland locations. Such large-scale changes could have resulted in higher population densities in the region (Bickel 1978a:9), particularly in low-lying areas located near the newly forming margins of the ocean and Bay.

To date, only one Early Holocene-age coastal site has been identified in the San Francisco Bay Area, this being CA-SON-348/H at Duncans Point cave (Jones 1992; Schwaderer 1992). Investigators generally attribute the scarcity of early coastal sites in the Bay Area to rising sea levels along the California coast (Atwater 1979; Bickel 1978a; Jones 1992). It is likely that older archaeological sites that were not destroyed by erosion from the advancing sea are associated today with submerged landforms that exist well below sea level (Atwater 1979; Bickel 1978a; Louderback 1951:87). Thus, the paucity of early archaeological sites in the Bay Area is partly a consequence of post-Pleistocene geological processes that significantly reconfigured the landscape. This suggests that there is a high potential for submerged prehistoric archaeological remains in some offshore segments of the PRNS-GGNRA.

Hillslopes and Colluvial Deposits

Most of the landscape in the PRNS-GGNRA is composed of bedrock ridges and hillslopes that predate human occupation of the region, including most of the Point Reyes peninsula, Bolinas Ridge, the Marin Headlands in Marin County, much of the Crystal Springs Reservoir in San Mateo County, and small portions of the San Francisco peninsula. The topography of these areas is characterized by “rugged ridges, spurs, and steep-sided canyons, some of which widen near their mouths into flat-floored valleys,” and “steep sea cliffs, commonly sculptured by landslides that have left near-vertical scarps along the Pacific Coast” (Bedrossian 1974:75). Thus, the hillslopes represent areas were sediments have generally been removed by erosional processes such as mass wasting, landslides, debris flows, soil creep, and sheet wash. As a result, colluvial deposits that are usually less than 1.0 m (3 ft.) thick cap most of the hillslopes (Kashiwagi 1985). Many of the landslides associated with the hillslopes are relatively recent geologic features, with some still actively forming. Some low-lying areas of the hillslopes contain basins, fans, hollows, footslopes, ravines, and saddles that have served to store sediments removed from the adjoining slopes. These colluvial landforms are generally small and occur in many isolated areas within the hillslopes that have not been mapped in great detail (Figures I.5 and I.6).

Geologic studies indicate that Bay Area hillslopes stored colluvium less frequently during Late Pleistocene and Early Holocene times than in later periods (Dietrich and Dorn 1984; Dietrich, Wilson, and Reneau 1986; Reneau et al. 1986, 1990; Rypins et al. 1989). Since the mobilization of debris-flows and colluvial landslides is generally associated with periods of intense rainfall (Rypins et al. 1989:84), the trend toward colluvial storage
Figure I.6. Distribution of Quaternary Geological Deposits in the Southern Point Reyes, Bolinas, and Marin Headlands Areas

Key:
af - Artificial fill deposits
Qha - Holocene alluvium
Qoa - Early to Middle Pleistocene alluvium
Qmt - Early to Middle Pleistocene marine terrace
br - Pre Quaternary bedrock

(Adapted from Knudsen et al. 1999a)
may signal an overall lowering of storm intensity during the Holocene (Dietrich, Wilson, and Reneau 1986). On the Point Reyes peninsula, rapid colluvial deposition occurred more than 12,000 years ago, then alternated with soil formation and minor debris-flows until about 8,300 years ago (Rypins et al. 1989:84). After this, colluvial deposition was slower and relatively continuous (Rypins et al. 1989:77), suggesting that deposition was triggered by “direct meteorologic control on erosion” (Rypins et al. 1989:84). This sequence of climatically driven changes suggests that most colluvial deposits were formed after initial human occupation of the coastal region.

A comparison of radiocarbon dates indicates that colluvial deposits in and near the PRNS-GGNRA range from Late Pleistocene (17,715 cal B.P.) to Late Holocene (655 cal B.P.) in age (Figure I.7). The distribution of the dates suggests that colluvial deposition occurred most frequently during the Late Pleistocene and Early Holocene, and least frequently during the Middle Holocene. It appears that colluvial deposition resumed sometime between 1820 and 655 cal B.P., after a prolonged period of relative hillslope stability (Figure I.7). Buried soils dating to the Late Pleistocene and Early Holocene have been identified within colluvial deposits located along the Point Reyes coast (Rypins et al. 1989). Soils buried by 1.0 to 3.0 m (3.0 to 9.8 ft.) of colluvium have been dated between 1215 ± 40 B.P. (1145 cal B.P.) and 1950 ± 35 B.P. (1900 cal B.P.) from bedrock hollows on Inverness Ridge (Reneau and Robinson 1988:129). Figure I.7 shows the depth of the Late Pleistocene and Early Holocene-age colluvium ranging from 2.0 m (6.5 ft.) to 6.7 m (22 ft.) below surface, with most occurring around a depth of 3.0 m (9.8 ft.). By comparison, the depth of the Late Holocene-age colluvium ranges from near the surface to a depth of 3.0 m (9.8 ft.), with most deposits occurring at depths of 1.0 m (3 ft.) or less (Figure I.7).

It seems reasonable that prehistoric people would have been attracted to some of the low-lying hillslope areas, particularly those located near springs or waterways. Given that colluvial deposition may have occurred most frequently during the Late Pleistocene and Early Holocene, the remains of early human use and occupation are more likely to be buried by colluvial deposits than are later remains. Given these factors and the on-going nature of colluvial deposition, there is a moderate potential for buried archaeological remains to be associated with some colluvial landforms in PRNS–GGNRA.

Valleys and Alluvial Deposits

There are a series of relatively small valleys in the PRNS–GGNRA that contain alluvial deposits (Figures I.5, I.6, I.8). Most of the valleys were formed by stream erosion of the underlying bedrock; the largest of these valleys, however, was formed by subsidence along portions of the San Andreas Fault. In either case, the alluvial deposits on the floors of these valleys represent multiple cycles of erosion and deposition formed by flood events in or near stream channels. Geologic mapping indicates that these deposits within PRNS–GGNRA range from Early Pleistocene to recent in age, with most dating to the Holocene (Knudsen et al. 2000). Many of the archaeological sites in the PRNS–GGNRA are located along stream channels that contain alluvial fan or floodplain deposits As such, it is possible that buried archaeological remains may be associated with alluvium that postdates human occupation of the region.

In the Los Vaqueros area of eastern Contra Costa County, geoarchaeological investigations revealed that three or more episodes of deposition were responsible for
Figure 1.7. Comparison of Radiocarbon Dates from Selected Natural Contexts and Archaeological Sites in Marin, San Francisco, and San Mateo Counties
Figure I.8. Distribution of Quaternary Geological Deposits in the Crystal Springs Reservoir Area

KEY:
al - Artificial fill deposits
afb - Artificial fill over Bay Mud
Qha - Holocene alluvium
Qhf - Holocene alluvial fans
Qa - Latest Pleistocene to Holocene alluvium
Qf - Latest Pleistocene to Holocene alluvial fans
Qpa - Latest Pleistocene alluvium
Qpf - Latest Pleistocene alluvial fans
Qof - Early to Late Pleistocene alluvial fans
br - Pre-Quaternary bedrock
Figure I.9. Generalized Cross Section of Major Geological Deposits in Fort Baker Valley, Marin County
the formation of a 15,000-year-old alluvial sequence in the Kellogg Creek valley (Meyer and Rosenthal 1997). Each of these depositional episodes was followed by a separate period of landform stability and soil formation during the Early, Middle, and Late Holocene. Deeply buried soils in the valley were found to contain Early Holocene-age archaeological deposits, some of the oldest yet identified in the region. The nature and timing of the Los Vaqueros depositional sequence is comparable to the depositional histories identified in other Bay Area valleys (Banks, Orlins, and McCarthy 1984; Borchardt 1992; Helley et al. 1979; Meyer 1998; Origer 1993; Pape 1978; Rogers 1988), suggesting that these changes may have been widespread and roughly synchronous (Meyer 1996). The findings from Los Vaqueros suggest that alluvial landscape evolution dramatically affected the nature and completeness of the archaeological record in the valleys of the region (Meyer and Rosenthal 1997:V.15).

Radiocarbon dates from alluvial deposits in and near the PRNS–GGNRA range from Late Pleistocene (14,345 cal B.P.) to Historic (130 cal B.P.) in age (Figure I.7). The dates suggest that alluvial deposition was most frequent and/or widespread during the Late Holocene, and least frequent and/or widespread during the Middle Holocene. It also appears that there was significant alluvial deposition during the Late Pleistocene and earliest Holocene, between 14,345 and 10,740 cal B.P. Radiocarbon dates from buried soils tend to be Late Holocene in age, with most clustered between 3080 and 2010 cal B.P., although older buried soils certainly exist. At Fort Baker in the PRNS-GGNRA, soils buried at depths of 1.3 to 1.9 m (4.2 to 6.2 ft.) were dated between 2940 ± 70 B.P. (3080 cal B.P.) and 2070 ± 70 B.P. (2010 cal B.P.) in the western arm of the main valley (Stewart, Meyer, and Newland 2003), as shown in Figure I.9. Figure I.7 shows that the depth of the Late Pleistocene and Early Holocene-age alluvium ranges dramatically from 43.0 m (141 ft.) bmsl to 3.2 m (10.5 ft.) below the present ground surface. By comparison, the depth of the Late Holocene-age alluvium ranges from less than 0.3 m (1 ft.) to more than 6.1 m (20 ft.) below surface (Figure I.7). Several buried archaeological sites have been identified in the Bay Area that are associated with soils buried by alluvium, most which date to the past 4,000 years or less.

Paleoseismology studies of alluvial deposits have been conducted in the Olema Valley and Crystal Springs Reservoir portions of the PRNS-GGNRA to understand the behavior of the San Andreas Fault (Grove n.d.; Grove and Niemi 1999; Hall and Hughes 1980; Hall, Wright, and Clahan 1995; Prentice, Niemi, and Hall 1991). These studies provide a wealth of detailed information regarding the age, nature, and extent of alluvial landforms in these valleys. Most importantly, these studies indicate that the alluvial deposits in these valleys tend to be quite young, and that many older landforms are buried by younger alluvium.

In Olema Valley, as seen in Figure I.10, the late Pleistocene-age Olema Creek Formation (OCF) is overlain by a series of younger terraces and alluvial deposits (Qt1, 2, 3, and Qal) along portions of Olema Creek. The age of the three terraces is not known, but Grove (n.d.) suggests that the Qt2 and Qt3 terraces formed during the Late Pleistocene, while the Qt1 terrace formed during the Pleistocene–Holocene transition. The Qal alluvial deposits are estimated by Grove to be “recent,” or Holocene in age. Radiocarbon dates ranging from 1850 ± 50 to 1910 ± 70 (1820 to 1870 cal B.P.) were obtained from a channel buried by Qal alluvium at the Vendanta Wind Gap (Niemi and Hall 1990). The buried
channel represents the former course of Gravel Creek, which may have become dormant after it was offset by slippage along the San Andreas Fault (Prentice, Niemi, and Hall 1991:29). The age and extent of these deposits suggests that the potential for buried archaeological remains is greatest in the northern part of Olema Valley, where large deposits of Holocene-age alluvium (Qt1 and Qal) are present (Figure I.10). Although limited information is currently available, alluvial deposits along other portions of the San Andreas Fault, such as those in the Crystal Springs Reservoir area of the southern PRNS-GGNRA, may have a depositional history that is similar to that in Olema Valley.

One of the earliest prehistoric sites yet identified in the PRNS is the McClure site (CA-MRN-266), which is associated with alluvial deposits located at the base of the hillslopes on the east side of the Point Reyes peninsula near Tomales Bay. The site reportedly contains a younger component (less than 1,000 years old) that is located at or near the ground surface, and an earlier component (more than 1,000 years old) that is at least 0.75 m below the surface (Beardsley 1954). Stratigraphic cross sections of the site suggest that the earlier component is associated with a buried soil (Level Ic - compact brown sand) that is overlain by a layer of naturally deposited sterile sand (Level Ib), and finally by “Level II” deposits that contain the later component (see Beardsley 1954: Figure 9). Given the apparent age and stratigraphic context of this site, it seems likely that alluvial deposits have buried many other Archaic-period sites in the PRNS-GGNRA.

Two buried prehistoric archaeological deposits (Pelican Site and Lower Fan Site—trinomials not yet available) were recently discovered as part of a geoarchaeological study of Big Lagoon at Muir Beach in Marin County (Meyer 2003). Both deposits were associated with a buried soil formed on the distal portions of alluvial fans that were overlain by more than 1 meter of sediment. Charcoal collected from a depth of about 1.5 to 1.9 m in the Lower Fan site produced a radiocarbon date of 230 + 30 B.P., or 290 cal B.P. (Beta-178505). Additional dates obtained from the estuarine deposits indicate that at least 1.0 m of sediment has been deposited in or near the lagoon over the past 300 years.

Prehistoric people were attracted to the valleys within the PRNS-GGNRA because they provided suitable locations for settlement and convenient access to important resources. Studies in the region show that these valleys were subject to repeated episodes of alluvial deposition and subsequent periods of landform stability during the Holocene that could have buried and preserved archaeological sites, and did in some cases. At the same time, stream incision and/or lateral channel migration within active floodplains likely redeposited or destroyed some archaeological deposits, particularly older ones. Given that alluvial deposition may have been most frequent and/or widespread during the Late Holocene, evidence of human use and occupation dating to more than about 3,000 years ago is more likely to be buried by alluvial deposits that are less than about 3,000 years old. As such, there is a high potential that some alluvial deposits in PRNS-GGNRA contain buried archaeological remains.

**Sand Dunes and Dune Fields**

Sand dunes are transient, relatively unstable landforms formed by wind-related (eolian) processes that are sensitive to minor changes in topography, vegetation, sediment supply, and sea levels (Carter, Nordstrom, and Psuty 1990:4-5). As such, the formation and migration of dune deposits can reflect a variety of environmental changes. Sand dunes
Figure I.10. Distribution of Geological Deposits in the San Andreas Fault Zone, Marin County
and extensive dune fields cover portions of the Point Reyes and San Francisco peninsulas that lie within the PRNS-GGNRA (Figures I.5 and I.11). Geologic mapping indicates that the dunes range from Pleistocene to Holocene in age (Clark and Brabb 1997; Knudsen et al. 2000), with likely areas of Holocene-age dunes remaining unmapped (Knudsen et al. 2000:A-7). Given the apparent age and depositional nature of the dunes, they have potential to contain buried archaeological remains.

In its original state, the sand dunes of the San Francisco peninsula represented one of the four most extensive dune complexes on the California coast (Cooper 1967:42). This vast dune field originally stretched across the entire width of the peninsula and southward along the coast into San Mateo County, which includes areas such as Fort Funston, Fort Mason, Ocean Beach, and the Presidio. These dunes were likely formed by the prevailing westerly winds that transported loose sand from Ocean Beach and Bakers Beach across the nearly level, poorly vegetated terrain to the east (Schlocker 1974:78-80). The dunes once formed a series of transverse-ridges that were characterized by narrow, almost linear dune crests and wide interdune troughs. Because dunes tend to stabilize in protected areas, the dunes are generally thicker on the eastern or leeward side of prominent bedrock hills and ridges on the peninsula (Schlocker 1974:78-80). W.P. Blake described the highly variable nature of the dunes in 1857:

Most of the hills in the city and its vicinity, where they were partly sheltered from the wind, are, or were, covered with a thick growth of dwarf trees and shrubs (chamisal), which prevented the wind from acting upon their surfaces and removing the sand. The progress of such hills is not uniform and constant, for, under certain circumstances, they remain stationary for long periods. Whenever the vegetation is removed, or a cutting is made, and the wind is allowed to act upon the surface, or to strike a hill in a new direction, the motion of the sand is rapid, and a large hill is soon carried away and piles up in a protected place, where the sand remains, secure from further violent action [1857:160-161].

While the extent of the dunes on the northern San Francisco peninsula is well-documented, the age and evolution of these dunes are only partly understood. In his study of dunes along the California, Oregon, and Washington coasts, Cooper (1967) identified two major episodes of dune formation during the Holocene that he correlated with significant sea-level changes. Although Cooper suggested that dunes on the east side of the peninsula are older than those on the west side, it is more likely that easterly dunes were reworked from older westerly dunes. Two different generations of dunes separated by bay mud and clay were recognized in borings in the Market Street area, east of the Civic Center on the eastern side of the peninsula (Schlocker 1974:80).

Older and younger dune deposits were also identified at a prehistoric archaeological site (CA-ALA-17) located across the Bay in west Oakland. Geoarchaeological investigations at the site determined that the cultural deposits overlie a buried dune that was radiocarbon-dated to 5400 cal B.P. It appears that there was an episode of dune instability and migration sometime between 5,000 and 4,000 years ago, which was followed by dune stability and human occupation by at least 3,700 years ago, as indicated by radiocarbon dates from archaeological materials in the overlying dune deposit (Jones n.d.).
Figure I.11. Distribution of Quaternary Geological Deposits on the Northern San Francisco Peninsula
Radiocarbon dates indicate that most of the dunes on the San Francisco peninsula formed during the Holocene. A radiocarbon date obtained from bay mud near the Civic Center indicates that the overlying dune sands are less than 2,000 years old at that location (Kelly, Spiker, and Meyer 1978). In the Presidio of the PRNS–GGNRA, radiocarbon dates from an alluvium pond (Mountain Lake) located in the dunes indicate that the dunes had stabilized more than 1,665 years ago in that area (Reidy 2001). A geoarchaeological study identified multiple dune deposits in portions of the Central Freeway corridor that range in age from Late Pleistocene to the Historic period (Mc Ilroy, Meyer, and Praetzellis 2001:42). These dunes were separated by buried soils that dated between about 4,960 and 140 years ago. Dunes located in the northern part of the corridor closest to the PRNS–GGNRA contained multiple weakly developed buried soils that ranged in age from about 1400 to 400 cal B.P. The presence of multiple dunes and weakly developed buried soil indicates that the Central Freeway portion of the dune field was subject to repeated cycles of dune migration during the Holocene. Radiocarbon dates from archaeological sites (CA-SFR-112 and -113) associated with buried dunes in downtown San Francisco confirm that parts of the dune field were stable and occupied by people between 2085 to 1155 cal B.P. (Pastron and Walsh 1988a, 1988b, 1988c). Some of the cultural deposits at these sites were buried 3.0 to 5.0 m (9.8 to 16.4 ft.) below the present ground surface. Thus, it appears that the San Francisco dune complex was actively forming during the Middle and Late Holocene, and even during the Historic period.

Deposits of older and younger dunes are also recognized on portions of the Point Reyes Peninsula. Older (Pleistocene-age?) dunes are mapped at isolated locations along the coast between Point Reyes and McClure’s Beach, while younger Holocene-age dunes are nearly continuous along an 11-mile stretch of the coast (Figure I.5). Stable and active Holocene-age dunes extend as far as 1 mile inland from the present coastline (Minard 1964:30). Cooper provides the following explanation for the sequence of dunes observed at Point Reyes:

Apparently, at an earlier time—which may well have been the last glacial maximum—sea level was considerably lower and the shore farther out than now. Littoral drift from the north was unimpeded by promontories and the shore more receptive. Dune sand accumulated in quantity along the west flank of the peninsula. With the ensuing rise of sea level the dune belt moved inland with the retrograding shore. Obstacles to littoral drift increased, the most important being Tomales Point. Reduction in fresh supply of sand accompanied by decrease in receptivity of shore due to development of cliffs led to today’s conditions—inland dune advance dependent largely upon reactivation of materials inherited from an earlier time [1967:41].

The younger dunes are often separated from the older dunes by a pronounced buried soil that exhibits well-developed subsurface horizons (Minard 1964:30, 1971:98-100). Figure I.12 shows the general relationship between the older and younger dunes that back Sculptured Beach at Point Reyes. At some localities, the dunes contain buried soils that are less well-developed and may represent intermediate-age dunes (Minard 1964:30, 1971:100-102). This suggests that the dunes were formed by multiple episodes of sand migration and subsequent periods of dune stability. Minard (1971:144-145) reasoned that
the buried soils were formed during periods of dune stability that coincided with previous low stands of Late Pleistocene sea levels. While the lower buried soil is likely Late Pleistocene in age, the upper buried soil may be Holocene in age, as are soils buried by dunes along other portions of the coast (Jones n.d.; McIlroy, Meyer, and Praetzellis 2000; Milliken et al. 1999; Orme 1991; Schlocker 1974). While the exact age of the buried soils is not known, it appears that relatively stable dunes were available for human occupation at different times during the Late Pleistocene and Holocene.

Many prehistoric sites along the California coast are associated with dune deposits because they tend to be located near the mouths of streams or rivers that form estuaries along the coast (Jones 1992). Along the Monterey coast at site CA-MNT-234, people continued to use and occupy dunes for more than 8,000 years, despite active dune formation and migration during the Middle and Late Holocene (Milliken et al. 1999:59). A study of radiocarbon dates from buried paleosols and archaeological sites associated with coastal dunes at Morro Bay in San Luis Obispo County indicates that the dunes were formed by three major phases of development around 4000 B.P., 1700 B.P., and 200 B.P. (Orme 1991). While the phase of dune activity around 1,700 years ago is associated with widespread devegetation resulting from fire that may have been “set either deliberately or accidentally by human beings” (Orme 1991:328), the latest phase of dune activity is probably related to increased human settlement over the past 200 years. Although no buried prehistoric sites are yet known to be associated with dune deposits in the PRNS-GGNRA, similar patterns of human land use may be detected in the dune deposits.

If people occupied the dunes during the Late Pleistocene or Holocene, then it is quite possible that relatively intact concentrations of archaeological materials were buried and preserved by dune migration, particularly at more inland locations. It is also possible that sea-level rise and coastal erosion either submerged and/or destroyed many older archaeological sites that may have been associated with dune deposits. Given this and the apparent timing of dune formation, later periods of human use and occupation are likely to be better represented in the dune deposits than are earlier periods. These factors suggest that the dunes have a moderate to high potential of containing buried archaeological remains, particularly those that date to the past 5,000 years or less.

Coastal Erosion and Landforms

Steep bluffs, precipitous cliffs, and rocky headlands with seastacks and wave-cut benches characterize most of the PRNS–GGNRA coastline. This rugged coast was sculpted by a complex combination of erosional processes that are related to sea-level rise, wave height, wave exposure, and the nature and extent of the materials that form the shoreline (Griggs and Savoy 1985:28). Coastal processes have formed most of the distinctive coastal landforms (seaciffs, seastacks, beaches, and dunes) over the past 5,000 years as sea levels approached their present elevation (LaJoie and Mathieson 1985).

Most coastal erosion occurs when waves undercut existing landforms, resulting in slumps, landslides, and rockfalls. People also cause coastal erosion by removing natural protection, such as sand or vegetation, and by building barriers that interrupt the natural transportation of sand. Wave-induced erosion is an on-going process that can occur rapidly in association with large storm events. Erosion occurs most rapidly along coastlines that lack protective sandy beaches—those that are oriented roughly perpendicular to the
Soils buried by older and younger sand dunes on Tomales Point

Figure I.12. Buried Landscapes Identified on the Point Reyes Peninsula

Multiple buried soils in alluvial terrace at Sculptured Beach (adapted from Rypins et al. 1989: Figure 7)
prevailing wave direction. Coastlines composed of hard rocks, such as granite or greenstone basalt, erode very slowly compared to coastlines that consist of softer sedimentary rocks or unconsolidated deposits like alluvium, colluvium, or dune sand. The western part of Fort Funston in the PRNS–GGNRA is an example of a coastline that is undergoing relatively rapid erosion due to a combination of these conditions and processes.

The rate of coastal erosion can vary dramatically from one location to the next depending on the factors outlined above. Although short-term erosion rates are related to an idiosyncratic combination of natural and human-caused erosive agents, the use of average, long-term, regional coastal erosion rates is likely valid over thousands of years (Kuhn and Shepard 1979). Geologic studies indicate that historic erosion rates along the San Mateo coast range from nearly zero to as high as 3.0 m (10 ft.) per year (Griggs and Savoy 1985). Historic maps indicate that the sedimentary rock that forms the tip of Point Año Nuevo has eroded at a rate of about 2.7 m (9 ft.) per year over the past 300 years. Other areas of sedimentary rock that form many of the seacliffs in or near the PRNS–GGNRA are retreating at average rates of about 15 to 30 cm (6 to 12 in.) per year. Records show that the cliffs between Bolinas and Duxbury Point have receded at an average rate of 15 to 60 cm (6 to 24 in.) per year, with localized recession of more than 1.0 m (3 ft.) per year in areas where the rock is fractured and less competent (Gregg and Savoy 1985:129). In contrast, coastlines backed by hard bedrock, such as some of the rocky bluffs between the Golden Gate and the Cliff House in PRNS-GGNRA, are relatively resistant to wave attack and erosion. If it is assumed that the average erosion rate for hard-rock coasts is four to five times slower than the average rate for soft-rock coasts, then the former may range from almost zero to as much as 10 cm (4 in.) per year. These rates provide a basis for estimating the amount of land that may have been removed by erosion along different parts of the PRNS–GGNRA coastline.

First, it is important to note that previous high stands of the sea had previously leveled much of the continental shelf, leaving a relatively level landscape exposed when the sea retreated during the last glacial maximum. Thus, the sea had to first advance over the pre-existing shelf before it reached the former Pleistocene-age coastline. As such, most of the erosion of the outer coast occurred after sea levels began to reach their former high-stand elevations about 6,000 years ago, with some central California coastlines retreating as much as 1 mile between 5,000 and 4,000 years ago (LaJoie and Mathieson 1985:143).

Based on erosion rates derived from the work of LaJoie and Mathieson (1985), Figure I.13 shows that hard-rock coastlines may have retreated as much as 600 m (0.37 mi.) during the past 6,000 years. During the same period, coastlines composed of sedimentary rock and/or unconsolidated deposits may have retreated at least 800 m (0.5 mi.), or as much as 3,600 m (2.2 mi.). Thus, it appears that at least 100 m (328 ft.) have been lost every 1,000 years from soft-rock coastlines over the past 6,000 years. At the same time, hard-rock coasts could have lost 10 m every 1,000 years, or 6 m (32.8 ft.) over the past 6,000 years, even if the average erosion rate was only 1.0 cm per year.

Given that people used and/or occupied portions of the PRNS–GGNRA coast since at least the Middle Holocene, it seems likely that many of their activities would have been conducted in low-lying, protected areas that contained sand dunes, fans, and floodplains. Because these landforms are particularly vulnerable to coastal erosion, it is very likely
that associated archaeological sites either were destroyed or will be destroyed by these ongoing processes. At the same time, it is possible that some older sites could have survived in areas that are underlain by hard bedrock, such as the Early Holocene site (CA-SON-348/H) identified at Duncans Point on the Sonoma County coast. Consequently, it is important to consider the effect of coastal erosion on the nature and completeness of the archaeological record in different parts of the PRNS–GGNRA.

**LANDSCAPE EVOLUTION AND HUMAN OCCUPATION**

Researchers in California have often interpreted the frequency and distribution of Late Holocene archaeological deposits as prima facie evidence of relatively abrupt settlement and population changes beginning in the upper Archaic and Emergent periods (e.g., Bouey 1987:66; Broughton 1994; Schulz 1981:184). At first glance, the predominance of Late Archaic and Emergent-period sites in California seems to support the notion of population increase. Current models view these demographic changes as attendant with more intensive subsistence strategies, which eventually led to increased organizational complexity (Basgall 1987; Beaton 1991; Bouey 1987; Broughton 1988, 1994; Jones 1992). These models suggest that the economic intensification characteristic of later adaptations
Part I – An Overview of Geoarchaeological Research Issues

was initiated by an imbalance between human population and available resources during the Middle Archaic.

While it is reasonable to assume that late Archaic and Emergent-period populations were greater than those of preceding periods, the mechanisms and overall trajectories of prehistoric population growth in California are poorly understood (Beaton 1991:950-951). This situation is largely a product of the paucity of Lower to Middle Archaic archaeological deposits that can provide direct evidence of human settlement and population. Some researchers have acknowledged that large-scale landscape changes have likely buried these older sites in central California (Banks, Orlins, and McCarthy 1984; Bickel 1978a; Beaton 1991:948; Fredrickson 1980; Jones 1992:8; Schulz 1981:184), an assumption verified by the discovery of deeply buried archaeological sites in the Bay Area that date from 5,000 to nearly 10,000 years ago (Henn, Jackson, and Schlocker 1972; Hildebrandt 1983; LaJoie, Peterson, and Gerow 1980; Meyer and Rosenthal 1997; Origer 1993). Even so, there has been no systematic investigation of the potential influence of large-scale geological processes on regional site-distribution patterns in the San Francisco Bay Area.

In other parts of North America, buried sites often supplement portions of the archaeological record that were otherwise unknown or underrepresented (Bettis 1995). As such, the investigation of buried sites can provide unique research opportunities for archaeological studies that seek to understand the cultural history and/or settlement pattern of an area or entire region. Another research value of buried sites is related to the process of burial, which often preserves the systemic context of archaeological materials that would otherwise be disturbed or destroyed by on-going processes at or near the surface. Buried sites can also contain considerable information about the nature and timing of past events and environmental conditions that contributed to their burial (Waters 1992).

RESEARCH QUESTIONS

Based on the foregoing review, the following issues and questions provide a direction for future geoarchaeological research in the PRNS–GGNRA:

1. Do the natural geologic deposits in the PRNS–GGNRA contain evidence of past environmental conditions (pollen, macrofossils, datable organics, etc.) that contributes to an understanding of landscape evolution and human occupation? Is there evidence that human land use and/or settlement patterns were altered in response to local or regional landscape changes? If so, what are the nature, timing and extent of these human responses?

2. What is the depositional sequence of the natural landform–sediment assemblages in the PRNS–GGNRA? How do these sequences compare with those identified in other parts of the Bay Area? What do these sequences reveal about the nature, timing, and extent of landscape evolution?

3. Has sea-level rise and/or tectonic subsidence resulted in the submergence of any previously unrecorded archaeological deposits in the offshore segments of the PRNS–GGNRA? If so, what is the temporal patterning of these deposits? Have these deposits retained any archaeological integrity?
4. Do alluvial, colluvial, or dune deposits in the PRNS–GGNRA contain buried soils that were available for human use or occupation? Are buried archaeological remains associated with any of these former land surfaces? If so, what time periods are represented, and are different time periods better represented within different deposits?

5. Can more accurate estimates of the timing and extent of coastal erosion be developed and used to assess the relative completeness of the archaeological record in different segments of the PRNS–GGNRA? Can the estimates be used to identify areas where known coastal sites are in danger of being destroyed by erosion?

6. To what extent has the nature, completeness, and/or visibility of the archaeological record within the PRNS–GGNRA been structured by local geological processes versus large-scale landscape evolution?

**Data Needs**

Certain types of data must be identified, recovered, and analyzed in order to address the above questions regarding human occupation and landscape evolution in the PRNS–GGNRA. These data types include the following:

1. **Landform-Deposits**: Natural geologic deposits, soil/landform stratigraphy, buried soils, datable organics, paleoenvironmental evidence.

2. **Archaeological Remains**: Obsidian debitage (hydration analysis), temporally diagnostic artifacts, datable organics, discrete features, buried or submerged archaeological materials.

**GEOARCHAEOLOGICAL EXPLORATION**

One of the most difficult issues faced by archaeological investigations is the problem of locating sites that may be buried or submerged by natural geological processes such as those that have occurred in and around the San Francisco Bay Area. This problem is compounded in areas where sites may also be hidden beneath portions of the built environment, like those found in parts of the study area (e.g., Fort Baker, Fort Mason, Presidio). Consequently, buried sites are most often discovered after being inadvertently exposed by natural erosion or mechanical earth-moving, and only rarely are they intentionally found as a result of conventional surface surveys.

Based on the foregoing review, a geoarchaeological approach will likely be the most effective and efficient approach for identifying potential buried archaeological resources within the PRNS–GGNRA area. This approach attempts to locate buried archaeological resources by targeting segments of the landscape (landform-sediment assemblages, or LSAs) that were stable and available for human use and occupation at different times in the past. The approach attempts to rule out certain landform deposits that may have been either unavailable or too unstable. The primary goal of the approach is not to locate every buried site that may exist in a given study area, but rather to reduce the area and/or
volume of sediments that needs to be searched, thereby increasing the likelihood that potentially buried archaeological resources will be identified. The ability to locate buried sites depends on the whether or not sensitive LSAs are adequately explored for evidence of past human activity using appropriate methods and techniques.

As the landscape is forever altered by human use and development, it is increasingly important that archaeologists and cultural resources managers attempt to locate and evaluate buried sites before they are inadvertently destroyed (Meyer 1996). The discovery and analysis of previously unidentified archaeological sites is crucial for archaeological inquiry because without new or comparative data, many important questions regarding chronology, settlement, and subsistence cannot be properly addressed or answered, and current research questions cannot be confirmed, denied, or refined beyond our present understanding. Further, it is imperative that previously unknown sites are identified to insure that potentially important archaeological resources are not inadvertently affected. Thus, it is considered critical that research efforts are conducted to identify archaeological resources that may be buried and/or submerged within the PRNS–GGNRA area.
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