Geologic Resource Evaluation Scoping Summary
Channel Islands National Park, California

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The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a geologic resource evaluation report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible include a site visit with local experts.

On May 5, 2008, USGS geologists Dan Muhs, Scott Minor, and Randy Schumann led GRE scoping participants on a field trip to eastern Santa Cruz Island. Santa Cruz Island is the largest body of land off the coast of California. Scoping participants traveled across the Santa Barbara Channel via Island Packers. Anacapa Island was the first island to come into sight during the voyage. Field-trip stops highlighted rock types (i.e., Potato Harbor Formation, Monterey Formation, and Santa Cruz Island Volcanics), marine terraces, glacial-interglacial cycles (e.g., at Cavern Point), eolianite and other windblown deposits, Vertisols, paleontological resources (e.g., clam burrows in the Monterey Formation and *Glycymeris* shells in the Potato Harbor Formation), faults (e.g., Potato Harbor fault), microfaults, and other structures.

On May 6, 2008, the National Park Service held the discussion portion of the GRE scoping meeting for Channel Islands National Park at the headquarters building at Channel Islands National Park, Ventura, California. Chief of Natural Resources Kate Faulkner welcomed the group, highlighted some geologic-resource management needs, and later presented background information about the park. Guy Cochrane (USGS Coastal and Marine Geology Program) presented information about the California Coast State Waters Mapping Project, which is mapping seafloor and benthic habitats. Chris Wills (California Geological Survey) presented information about the state survey's mapping program, which is driven by population growth and development. Greg Mack (Pacific West Region) facilitated the assessment of map coverage, and Bruce Heise (Geologic Resources Division) led the discussion regarding geologic processes and features at the national park.

Scoping participants included NPS staff from the park, Mediterranean Coast Network, Pacific West Region, and Geologic Resources Division, and cooperators from Santa Barbara Museum of Natural History, U.S. Geological Survey, California Geological Survey, California State University Northridge, and Colorado State University (table 2).

Park and Geologic Setting

During her presentation, Kate Faulkner (Channel Islands National Park) referred to Channel Islands as "the Galapagos of North America" because of their wildness, isolation, abundance of marine life, and unique adaptations of terrestrial plants and animals, some of which are found nowhere else. In addition, the oldest human remains in North America were discovered here. Archaeological and cultural resources on the islands span a period of more than 13,000 calendar years (11,000 radiocarbon years). Paleontological resources reach back 17 million years to the Miocene Period.

Only 42 km (26 mi) from the Los Angeles megalopolis but worlds apart, Channel Islands National Park encompasses five of the eight California Channel Islands, which line the Santa Barbara Channel. From west to east, the park's islands are San Miguel, Santa Rosa, Santa Cruz, and Anacapa, with Santa Barbara farther south. Santa Catalina, San Nicolas, and San Clemente islands are not part of the national park.

San Miguel, the westernmost island, is possibly the wildest. With no regularly scheduled boat landings or docks, the island's beautiful, sandy beaches are difficult to reach, making them hallmark destinations. A stone monument above Cuyler Harbor commemorates Juan Rodriquez Cabrillo—the Portuguese explorer who sailed the Pacific Coast and set foot on the continent in 1542. He was thought to have died on San Miguel Island, but now historians suspect he may have died on another Channel Island.

In the 1930s the island was, according to Kate Faulkner, "a barren sand dune." The island is now 90% revegetated as a result of the removal of nonnative animals. The distinctive "caliche forests" occur on San Miguel (see "Eolian Features and Processes" section). San Miguel Island—13 km (8 mi) long and 6 km (4 mi) wide—has rocks with both sedimentary and volcanic origins (Weaver 1969; Weigand and Savage 1999). Quaternary eolian sands cover much of the island's bedrock.

Santa Rosa Island—16 km (10 mi) wide and 24 km (15 mi) long—is an island "in transition" with rapid recovery in riparian areas since the removal of nonnative species such as sheep, cattle, and pigs. Grazing and poorly engineered roads caused as much as 1.2 m (4 ft) of soil erosion in some places on the island, which exposes the tree roots of native island oaks. Sadly, few oaks remain, which has changed island hydrology and resulted in the lost ability of the island "to catch water." Scoping participants experienced this function via an audioclip that Kate Faulkner played during her presentation; participants could actually hear the capture of moisture as fog engulfed an oak grove. Santa Rosa Island is the second largest island in California and is the site of the discovery of both the pygmy mammoth (see "Paleontological Resources" section) and the earliest dated human remains in North America (~13,000 calendar years old). Santa Rosa Island is composed of Tertiary sedimentary rocks and Miocene volcanic rocks (Weigand and Savage 1999). Marine terraces are prominent on much of the island at lower elevations (Orr 1960; Pinter et al. 2001).

The Nature Conservancy and the National Park Service share the responsibility of preserving **Santa Cruz Island**. The island is 39 km (24 mi) long, 10 km (6 mi) wide, and covers 25,090 ha (62,000 ac). With the removal of sheep by 2000 and feral pigs by 2006, the island's ecosystem is starting to show the beginnings of recovery. Many of the island's archaeological sites have also been stabilized. Santa Cruz Island hosts Painted Cave, the largest sea cave in California and one of the largest in the world (see "Caves and Wave Erosion" section). Its 50-m- (160-ft-) wide entrance leads to a 0.4-km (0.25 mi) long tunnel; 24-m- (80-ft-) long boats can enter the cave. Volcanic activity between 19 and 13 million years ago formed the volcanic rocks that comprise much of the island's bedrock, although the Monterey Formation (marine shale) covers portions of the Santa Cruz Island Volcanics (Weaver 1969). Marine terraces dominate the geomorphology of the lower elevations of the island (Muhs et al. 2008).

Volcanic **Anacapa Island** is less than 400 ha (1,000 ac) and divided into three islets, which stretch about 8 km (5 mi) but span only 0.3 km (0.5 mi) in width. No fresh water occurs on the island. The island is recovering from a legacy of ranching and black-rat *(Rattus rattus)* infestation. Xantus's murrelet *(Synthliboramphus hypoleucus)*, a rare seabird threatened by predators introduced to its breeding colonies, nests on Anacapa Island. The Coast Guard also had a presence here; the historic lighthouse, built in 1932, is a popular hiking destination. Additionally, Chumash middens are a notable feature of the island. The waters surrounding Anacapa are the site of long-term monitoring of kelp forests, which has accumulated 25 years of data. Apart from the lack of Monterey Formation, eastern Santa Cruz Island and Anacapa Island have similar geologies. Santa Cruz Island Volcanics (basaltic andesite to dacite) of Miocene age dominate. Anacapa Isalnd also hosts beds of San Onofre Breccia (Scholl 1960). All three of the Anacapa islets host marine terraces (Valentine and Lipps 1963; Lipps 1964).

Tiny, 3-km^2 (1-mi^2) **Santa Barbara Island** is surrounded by cliffs and, therefore, has limited access. However, prehistoric people occupied this island, followed more recently by 250 years of intense human use and resultant erosion. The largest population of Xantus's murrelets has historically been on Santa Barbara

Island, though numbers have experienced a long, slow decline (Kate Faulkner, Channel Islands National Park, e-mail, July 30, 2008). Removal of feral rabbits has aided in vegetation recovery. Santa Barbara Island is composed almost completely of mafic volcanic rocks (Norris 1991). Like Santa Cruz and Anacapa, a series of marine terraces, many of them highly fossiliferous, dominate this island's geomorphology (Lipps 1968; Muhs et al. 2008).

The National Park Service is also steward of one nautical mile surrounding each of the islands. Thereby, half of the park's resources are submerged. Channel Islands National Marine Sanctuary—part of a network of 13 national marine sanctuaries and one national marine monument—encompasses six nautical miles surrounding the waters of Channel Islands National Park. The National Park Service is in partnership with the Channel Islands National Marine Sanctuary, administered by the National Oceanic and Atmospheric Administration and U.S. Department of Commerce, to protect natural and cultural resources within these waters.

Geologic Mapping Plan for Channel Islands National Park

During the scoping meeting, Greg Mack (Pacific West Region) showed some of the main features of the GRE Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRE Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRE Program and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, FGDC-compliant metadata, a Windows HelpFile that captures ancillary map data, and a map document that displays the map and provides a tool to directly access the HelpFile. Final products are posted at http://science.nature.nps.gov/nrdata/. The data model is available at http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm.

When possible, the GRE Program provides large scale (1:24,000) digital geologic map coverage for a park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands. Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management begins with the identification of existing geologic maps in the vicinity of the park. Scoping session participants then discuss mapping needs and select appropriate source maps (table 1) for the digital geologic data or, if necessary, develop a plan to obtain new mapping.

Table 1. Source Maps for Bedrock Geology of Channel Island National Park

Island	Format/Notes	Reference
San Miguel	Scale-stable Mylar	Weaver, D. W. 1969. *Geology of the northern Channel Islands, southern California borderland.* Scale 1:24,000. Special Publication. Upland, CA: AAPG and SEPM, Pacific Sections.
Santa Rosa	Digital data from U.S. Geological Survey; GMAP[1] 7393	
Santa Cruz	Scale-stable Mylar	
Anacapa	Paper	Scholl, D. W. 1960. Relationship of the insular shelf sediments to the sedimentary environments and geology of Anacapa Island, California. Figure 3 [general geologic map of Anacapa Island]. *Journal of Sedimentary Petrology* 30 (1): 123–139.
Santa Barbara	Paper	Kemnitzer, L. E. 1933. The geology of Santa Barbara Island, southern California. MS thesis, California Institute of Technology.

[1]GMAP numbers are identification codes for the GRE Program's database.

During scoping, participants agreed on the following mapping plan for Channel Island National Park:

- Digitize bedrock geology of Weaver (1969) for San Miguel and Santa Cruz islands. On July 3, 2008, the Pacific Section of SEPM (Society for Sedimentary Geology) granted the Geologic Resources Division permission to reproduce and republish the geologic maps contained in this publication. Dan Muhs (U.S.

Geological Survey) is facilitating the coordination and transfer of information of this map to GRE staff. As of September 2008, all Weaver maps had been scanned (Dan Muhs, U.S. Geological Survey, e-mail, September 15, 2008).

- Convert the digital data for Santa Rosa Island. These data are available from the U.S. Geological Survey at http://science.nature.nps.gov/nrdata/datastore.cfm?ID=21366. Scott Minor (U.S. Geological Survey) and Greg Mack (NPS Pacific West Region) have discussed Mylar scans and format preferences (i.e., 300dpi, grayscale, TIFF images). During the conversion process, GRE staff will conduct quality control and compare these data with the original Weaver (1969) map.
- Digitize bedrock geology of Scholl (1960) for Anacapa Island.
- Digitize bedrock geology of Kemnitzer (1933) for Santa Barbara Island.
- Convert digital offshore geology from the California Coast State Waters Mapping Project. Guy Cochrane (USGS Coastal and Marine Geology Program) estimated that the offshore geology for the Channel Islands to be completed by 2011.
- Include "topical" point, line, and polygon data from the U.S. Geological Survey as GIS layers. These data include ages and surficial deposits (e.g., marine terraces) relevant for determining the geologic and climatic history of the islands, site-specific fault measurements, and modified fault lines.

Since scoping, GRE and CGS staffs have been in contact regarding the production of a new Quaternary (surficial) map for all five islands. California Geological Survey geologists have submitted a proposal for support from the GRE Program to conduct this mapping. During scoping, park staff also expressed an interest in detailed landslide mapping to identify unstable areas that pose a threat to park infrastructure and resources. The California Geological Survey has submitted a proposal for GRE support to produce a landslide map of the park area. Depending on budget considerations, one or both of these proposals may be funded in 2009. Hence, the following have been added to the mapping plan:

- Convert digital surficial data from the California Geological Survey for all five islands.
- Convert digital data of the new CGS landslide map.

Geologic Features and Processes and Related Management Issues

The scoping session for Channel Islands National Park provided the opportunity to discuss management-related geologic issues and develop a list of geologic features and processes, which will be further explained in the final GRE report. During scoping, participants did not prioritize the issues, so they are listed alphabetically here.

Caves and Wave Erosion

Sea caves occur on all five of the islands in Channel Islands National Park. Though no formal inventory has been conducted, sources state that more than 380 sea caves occur in the Channel Islands (Kiver and Harris 1999). Faults and wave activity control the locations and formation of caves, as well as sea stacks, bridges, and arches. Arch Rock has become an icon for Anacapa Island and the national park, and Anacapa Island is known for its sea caves, upwards of 130 of them. Santa Cruz hosts Painted Cave, the largest sea cave in the park and one of the largest in the world.

Caves and smaller cavelets serve as habitat for birds. The national park hosts and protects 99% of the seabirds of California. Some species prefer the perched "dry" caves, which are in some cases uplifted former sea caves.

Marginally karstic dissolution features occur in carbonate sand.

Climate Change

Losing Ground: Western National Parks Endangered by Climate Disruption states, “A climate disrupted by human activities poses such sweeping threats to the scenery, natural and cultural resources, and wildlife of the West’s national parks that it dwarfs all previous risks to these American treasures” (Saunders et al. 2006). The authors contend that “a disrupted climate is the single greatest threat to ever face western national parks.” Because of the potential disruption that climate change could cause to park resources, including geologic features and processes, the GRE Program has begun to include a discussion of the effects of climate change on park resources as part of scoping meetings. During scoping at Channel Island National Park, participants mentioned the concern for rising sea levels, primarily because of the large number of threatened and endangered species endemic to the islands; these species “have nowhere else to go.” The waters surrounding the Channel Islands are the site of a major faunal boundary. Here, the northern California current collides with the warmer southern California countercurrent. The Channel Islands are also within a nutrient-rich zone of upwelling. Changes in wind patterns and ocean currents could alter this upwelling regime, which could affect all marine species. Additionally, changes in climate could affect storm activity and precipitation patterns, including fog.

Coastal Features and Processes

Coastal processes are also discussed in the “Eolian Features and Processes” and “Caves and Wave Erosion” sections of this summary. Suffice to say here that spectacular wave-cut benches with tide pools, world-class beaches (both sand and cobble beaches), and uplifted wave-cut benches (marine terraces) occur on all five of the islands in the park. A significant management concerns related to coastal processes is the reduction or loss of habitat as a result of shoreline retreat.

Disturbed Lands

Disturbed lands are those park lands where the natural conditions and processes have been directly impacted by mining, development (e.g., facilities, roads, dams, abandoned campgrounds, and user trails), agricultural practices (e.g., farming, grazing, timber harvest, and abandoned irrigation ditches), overuse, or inappropriate use. The NPS Disturbed Lands Restoration Programs, administered by the Geologic Resources Division, usually does not consider lands disturbed by natural phenomena (e.g., landslides, earthquakes, floods, hurricanes, tornadoes, and fires) for restoration unless influenced by human activities.

Staff at Channel Islands National Park has worked with the GRD Disturbed Lands Restoration Program to mitigate the effects of poorly engineered roads and past building sites on Santa Rosa Island. Additional restoration may include more roads, old fence lines and corrals, and abandoned mine land (AML) sites such as a quarry for Santa Barbara Island’s breakwater and a quarry at Frys Harbor.

Energy Development

Much of California’s oil industry is built on extracting petroleum and natural gas from structures in the Transverse Ranges, including reservoirs beneath the Santa Barbara Channel. Four wells and access roads on Santa Cruz and Santa Rosa islands attest to past interest in oil potential at the national park. However, these 1960s-era explorations resulted in no drilling for oil. Nonetheless, oil seeps and associated tar deposits occur on San Miguel and Santa Cruz islands (Kiver and Harris 1999). Though interesting, oil companies rarely drill these types of seeps because the breached or imperfect seal prevents commercial quantities of oil from accumulating (Kiver and Harris 1999).

San Miguel and Santa Rosa islands have fantastic wind resources, so future development of wind energy in the Channel Islands is a management concern.

Eolian Features and Processes

Sand dunes and sand sheets of multiple ages are primary eolian features at Channel Islands National Park. Windblown sand covers most of San Miguel Island, much of Santa Rosa Island, and a portion of Santa Cruz Island. Windblown silt from the mainland covers Santa Barbara and Anacapa islands and the eastern part of Santa Cruz Island.

San Miguel Island is known for its "caliche forest"—former trees and shrubs cemented by calcium carbonate and eroded by the wind. During the field trip, scoping participants saw a miniature version on Santa Cruz Island, which they referred to as the "caliche shrublands" in jest, though not a bad name in actuality. The caliche shrubland of Santa Cruz Island occurs in the Potato Harbor Formation. The much more extensive caliche forest of San Miguel Island is sometimes referred to as the "ghost forest" because of its deathly white appearance. The trees of the forest are casts of probable Pleistocene conifer species such as pine and cypress. These "rhizoconcretions" are notable for their size; a prime example is nearly 1.2 m (4 ft) in diameter and 9 m (30 ft) tall (Johnson 1967; Lamb 2000). Another interesting possible eolian feature in the Bechers Bay Formation is tafoni—natural honeycomb-like cavities that form via weathering, in this case hypothesized to be from wind scour. Good examples of tafoni occur at Point Bennett on San Miguel Island and in Lobo Canyon on Santa Rosa Island.

Fluvial Features and Processes

Flash floods can rage in major drainages on the islands, for instance the December 5, 1997, flood at Scorpion Ranch on Santa Cruz Island. Floods can also occur in coastal wetland areas such as Prisoners Harbor. Fluvial processes have created spectacular cut-and-fill alluvial features on three of the northern Channel Islands (i.e., San Miguel, Santa Cruz, and Santa Rosa). Coalesced alluvial fans called bajadas have also formed on Santa Rosa Island.

Past ranching activities and the introduction of nonnative ungulates have changed hydrologic processes. Ranchers, the Army Corps of Engineers, and the Navy channelized some streams. With the removal of ungulates and the cessation of ranching, the fluvial regime could return slowly to a more natural state. Arroyo cutting of late Holocene or historic age has been observed on the islands (Johnson 1980).

Hillslope Features and Processes

Guidebooks warn island visitors of "rugged relief and crumbling rock" (Morris 2003). Scoping participants noted extensive landslides, primarily in the Monterey Formation, but all rock types near steep sea cliffs are susceptible. In addition, soil slip and creep occurs on all islands, and liquefaction on slopes results in mudflows. Rotational slumps are also common; those surrounding Cuyler Harbor on San Miguel Island are quite spectacular. In short, nearly every type of mass movement imaginable happens at Channel Islands National Park. The "poster child" of mass wasting at Channel Islands may be the long gooseneck of Santa Cruz Island seen in aerial view, which probably formed at least in part by slumping on either side of the island.

Gravity-driven processes impact habitats, in some cases changing local hydrology and creating new ponds and wetlands. In other cases, landslides provide material that is reworked by the waves to create beaches. These processes also pose threats to infrastructure such as landing sites in coves, campgrounds, trails, and roads.

Lacustrine and Surface-Water Features and Processes

Lakes are not a common sight at Channel Islands National Park. Nonetheless, sandy San Miguel Island has ephemeral lakes that form in the interdune troughs of sand dune fields. These lakes last on the scale of weeks to months. Precipitation-related vernal pools are present in Lobo Canyon on Santa Rosa Island as well as areas of Santa Cruz Island. Springs and seeps bring freshwater to the surface.

Marine Features and Processes

"Geology as habitat" is a huge issue for managers at Channel Islands National Park. After observation of a submarine topographic map, the simple image of a smooth sea floor is quickly replaced by the bathymetric reality of submerged arches, pinnacles, canyons, and plateaus. Drowned sedimentary and volcanic rocks are eroded into sediments with particle sizes that range from sands on beaches and offshore shelves to boulder fields and large submarine slides. According to the park brochure, "this topography—shallow and deep, smooth and rugged, sunlit and dark—creates habitats for a diversity of species." In addition rocky reefs, both above and below the photic zone, and ocean currents also play an important role in the biodiversity of the islands.

During scoping, participants repeatedly discussed marine terraces. These features dominate the geomorphology of the low-elevation portions of all five islands. Perhaps the park's most famous marine-terrace locality is Inspiration Point on east Anacapa Island. Here, the waves are eroding the terrace into a knife edge. Marine terraces provide a wealth of information about past climate, sea-level rise, and recent tectonic uplift and deformation (see "Selected References" section).

Paleontological Resources

The most celebrated paleontological resource at Channel Islands National Park is the pygmy mammoth. During glacial periods of the Pleistocene, full-sized Columbian mammoths *(Mammuthus columbi)* apparently swam from the mainland to Santarosae—the "super island" formed from San Miguel, Santa Rosa, Santa Cruz, and Anacapa at lower sea levels (Johnson 1978, 1980, 1981). Over many generations, the mammoths decreased in height at the shoulder from 4 m (14 ft) to 2 m (6 ft), becoming *Mammuthus exilis*, a pygmy species unique to Santarosae (Lamb 2000). Investigators have found remains of pygmy mammoth on Santa Cruz, Santa Rosa, and San Miguel islands.

Many other Quaternary, Tertiary, and Cretaceous fossils occur at Channel Islands National Park. The inventory by Koch and Santucci (2003) provides baseline data. Marine terraces on Santa Cruz, Santa Rosa, San Miguel, and Anacapa islands host numerous fossil specimens: mollusks, crustaceans, and echinoderms (Orr 1960; Valentine and Lipps 1963; Lipps 1964, 1968; Johnson 1972). The San Diego Natural History Museum retains the more than 300 specimens collected from Santa Cruz Island and 1,000 specimens from Anacapa Island. The Natural History Museum of Los Angeles County houses collections from Santa Barbara, San Miguel, and Santa Rosa islands. Scoping participants mentioned a few distinctive Quaternary vertebrate fossils, including bird fossils on Anacapa Island, a flightless goose, and rodents, as well as some spectacular Tertiary fossils such as Turitellas (snails) and pectens (bivalves). Park staff would like investigators to conduct a thorough inventory of paleontological resources at the park.

Tectonic and Seismic Features and Processes

The tectonic setting of Channel Islands National Park is a diffuse transform plate boundary; the park is located in a broad zone of deformation where the North American and Pacific plates are moving past each other. Channel Islands National Park is situated on the northwest-moving Pacific Plate. Santa Cruz Island and the other northern Channel Islands lie along the southern margin of the western Transverse Ranges province and constitute a portion of an east-west trending anticlinorium—a composite anticlinal structure of regional extent composed of lesser folds—that also includes the Santa Monica Mountains (Gordon et al. 2001). Numerous dramatic faults (e.g., the Santa Cruz Island fault) and beautiful folds enliven island scenery. Faults have cut Quaternary marine terraces, and historic seismic activity in the Santa Barbara Channel attests to a long and continuing history of tectonism within and surrounding Channel Islands National Park. Both the U.S. Geological Survey (e.g., Quaternary fault and fold database) and California Geological Survey (e.g., Field et al. 2008) have data about seismic events in the vicinity of Channel Islands National Park.

Unique Geologic Resources

Geologic resources that may be considered unique include features mentioned in a park's enabling legislation, features of widespread geologic importance, geologic resources of interest to visitors, and geologic features worthy of interpretation. Many of these have been discussed in other sections of this scoping summary. The GRE Program also considers type localities and age dates as unique geologic resources. The Potato Harbor Formation and Santa Cruz Island Volcanics have their type localities in Channel Islands National Park. Various investigators have dated the volcanic rocks (K-Ar and Ar-Ar) and marine terraces (U-series ages of corals and relative ages of mollusks using amino acids) within the park (see "Selected References" section). The U.S. Geological Survey is dating sand dunes using radiocarbon ages of calcite in the rhizoconcretions.

Volcanic Features and Processes

Although various research has speculated about the Channel Islands being emerged volcanoes during the Miocene (e.g., Emery 1960), evidence does not support this notion. However, a mostly submarine volcanic history is undeniable, as evidenced in part by possible vent complexes on Santa Rosa Island and elsewhere. Each island was the site of ancient (Miocene) volcanism, with coverage ranging from 100% on Santa Barbara Island to a few dikes on San Nicolas Island (Weigand and Savage 2002). Volcanic rocks in Channel Island National Park include lava flows, flow breccias, sedimentary units composed exclusively of volcanic material, and dikes (Weigand and Savage 2002). Interesting volcanic features include pillow basalts that erupted in submarine conditions but are now displayed above water in the rocks of Santa Barbara Island. Some of the lavas on Santa Cruz Island also show evidence of submarine origins.

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Selected References

Dan Muhs (U.S. Geological Survey) provided PDFs of the following references for use in preparing the final GRE report and for the benefit of park staff. The references are formatted using The Chicago Manual of Style *and organized into various topics. Cited references are not repeated as selected references.*

Eolian Deposits and Processes

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