

Geologic Resource Evaluation Scoping Summary Cabrillo National Monument, California

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October 16, 2008

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U.S. Department of the Interior



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.

The National Park Service held a GRE scoping meeting for Cabrillo National Monument on May 6, 2008, at the headquarters building at Channel Islands National Park, Ventura, California. 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. 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 planning and the development needs of California. Andrea Compton (Cabrillo National Monument) provided background information about the national monument and highlighted some geologic resource management needs.

Participants at this meeting included NPS staff from Cabrillo National Monument, 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).

On August 8, 2008, Pat Abbott (San Diego State University) led a field trip in Cabrillo National Monument. Participants included park staff and volunteers, staff from the Cabrillo National Monument Foundation, and GRE staff from Colorado State University. Because the May 2008 scoping meeting took place in Ventura, California, participants did not have the opportunity to visit Cabrillo at that time. GRE staff coordinated this "follow-up" field trip to take place at the same time as the Environmental Systems Research Institute (ESRI) International User Conference in San Diego. During the field trip, participants made stops at the tide pools and along the Point Loma Trail within the national monument, and at a sewage treatment plant (outside the monument), which has good views of alluvial fan deposits. During the trip, participants discussed submarine fan deposits, marine terraces, paleontological resources, and geologic hazards. Notes from the field trip have been incorporated into this scoping summary.

Park and Geologic Setting

The Point Loma peninsula experienced nearly 80 million years of geologic history before Juan Rodriguez Cabrillo's landing at San Diego Bay 466 years ago. The War Department memorialized the explorer's accomplishments in 1913 with the proclamation of Cabrillo National Monument at the tip of the Point Loma peninsula; the National Park Service became steward of the site in 1933. A heroic statue of Cabrillo looks out over the bay that this Portuguese explorer first sailed into on September 28, 1542. The geologic features that mark this long history include the Point Loma Formation—a large Cretaceous (~76 million-year-old) submarine fan and associated debris flows, submarine channels, and trace fossils. Field trip participants noted many distinctive features of the submarine fan including Bouma sequences, ripple marks, flame structures, and oxidation banding (Liesegang rings); these will be highlighted and explained in the final GRE report.

Other geologic features at Cabrillo National Monument are Quaternary marine terraces, faults, coastal erosion features (e.g., tide pools), and eolian and colluvial deposits (Abbott and Rockwell 2004).

Since the time of Cabrillo's expedition to the West Coast, colonization followed by growth and development have altered the landscape. Sixteenth-century exploration, 19th-century lighthouses, and more recent military occupation are all elements of today's landscape at Cabrillo National Monument. During scoping, Andrea Compton (Chief of Natural Resources Management and Science) compared the peninsula to an island because of its confining aquatic borders and urban landscape. To the north is San Diego, to the east and south is San Diego Bay (and harbor), and to the west is the Pacific Ocean. In addition, the North Island Naval Air Station—across the bay—and the San Diego Airport—1 km (7 mi) to the northeast—impact the natural systems of the 600-ha (1,500-ac) peninsula. The monument contains 65 terrestrial hectares (160 ac) at the tip of the Point Loma peninsula and 49 offshore ha (120 ac). The portion of the peninsula not managed by the National Park Service is divided among the U.S. Navy, U.S. Coast Guard, City of San Diego, and U.S. Department of Veterans Affairs. All of these landowners have established the Point Loma Ecological Conservation Area (PLECA), which covers 268 ha (662 ac); this collaboration allows for management of the natural resources of the entire peninsula.

Geologic Mapping for Cabrillo National Monument

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 data products are posted at <http://science.nature.nps.gov/nrdatal/>. 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 each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain parklands. 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 and mapping needs in the vicinity of the park. Scoping session participants then select appropriate source maps (table 1) for the digital geologic data or develop a plan to obtain new mapping, if necessary.

Table 1. Source Maps for Cabrillo National Monument

GMAP ID ¹	Reference	Format	Notes
4879	Kennedy, M. P. 1975. Geology of the Point Loma 7.5' quadrangle, San Diego County, California. Scale 1:24,000. In <i>Geology of the San Diego Metropolitan Area, California, Section A</i> . Plate 3a: Western San Diego metropolitan area. Bulletin 200. Sacramento, CA: California Geological Survey.	?	Evaluate and add "missing attributes" for within monument boundaries.
Update of GMAP 74947	Kennedy, M. P., and S. S. Tan. 2008 <i>Geologic map of the San Diego 30' × 60' quadrangle, California: A digital database</i> . Scale 1:100,000. Sheet 1 of 2. Regional Map Series 3. Sacramento, CA: California Department of Conservation, California Geological Survey.	Digital data	Convert California Geological Survey digital data to GRE model.
	Tan, S. S. 1995. <i>Landslide hazards in the southern part of the San Diego metropolitan area, San Diego County, California</i> . Scale 1:24,000. Landslide Hazard Identification Map 33. Open-File Report OF 95-03. Sacramento, CA: Department of Conservation, Division of Mines and Geology.	Paper	Evaluate and potentially include data for within monument boundaries.

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

During scoping, participants agreed on the following mapping plan for Cabrillo National Monument:

- Convert the digital data of Kennedy and Tan (2008) to the GRE model. This digital database from the California Geological Survey provides both onshore and offshore geology at scale 1:100,000.
- For the area within the boundaries of Cabrillo National Monument, include any 1:24,000-scale attributes (e.g., offshore faults or landslide data) from Kennedy (1975).
- Evaluate and possibly include plates from Tan (1995) (e.g., landslide hazards). These plates are not available digitally.

After the field trip on August 8, 2008, Stephanie O'Meara (Colorado State University), Heather Stanton (Colorado State University), and Andrea Compton (Cabrillo National Monument) discussed the mapping plan. If the GRE digital map for the national monument is completed in early fiscal year 2009, which GRE staff thinks is probable, GRE staff could present the map to park staff during next year's ESRI user conference in San Diego. The conference is typically in late July or early August. Stephanie O'Meara, Heather Stanton, and perhaps other GRE staff will likely attend. The presentation would be a great opportunity to present the GRE digital geology map to park staff and for park and GRE staffs to work together using the data. It would also allow park staff to provide feedback about the GRE Program, including possible uses of the digital geology map at Cabrillo National Monument.

Geologic Features and Processes and Related Management Issues

The scoping session for Cabrillo National Monument 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 Coves

Much of the cliff erosion at Cabrillo National Monument is a result of the growth and collapse of sea caves. Ocean waves transport water and sediment, which abrade the fractured bedrock. Most caves are small, the largest being about 30 m (100 ft) long and 9 m (30 ft) wide. Generally the caves are not long lived and collapse because the bedrock (sandstone and siltstone) is not very coherent. The caves are not suitable as habitat for bats, but birds dwell in some of the larger caves.

Coves along the shoreline form when the roofs of sea caves collapse. According to Abbott and Rockwell (2004), "many lovely coves have been destroyed in the name of coastal protection by filling them with riprap (large boulders) and building cement walls. Through these efforts may slow the rate of erosion somewhat, they severely diminish the beauty and uniqueness of the cliffs."

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 to park resources as part of scoping. During the meeting for Cabrillo National Monument, participants mentioned the possibility of higher sea levels changing the ocean-land access points, which are economically important for the ports in the San Diego Bay. In addition sea-level rise will impact the ecologically significant intertidal zone. Climate change will affect park infrastructure, including buildings and parking lots, but the infrastructure with the biggest risk for damage are non-National Park Service structures such as the new Point Loma lighthouse and the sewage treatment plant.

Coastal Features and Processes

During storms, high-energy waves erode the faces of cliffs, which are composed of the Point Loma Formation; sections slough off as a result of storm activity. Southeast-facing slopes are particularly prone to wave activity and are a source of weathered sand; small beaches composed of this material occur on the bayside of the monument. Riprap and shotcrete along the coast is meant to stabilize the shoreline. Such modifications change tidal processes.

Wave activity also promotes the formation of caves and coves (see “Caves” section) and is instrumental in the formation and collapse of pillars and arches.

The bay is naturally muddy or sandy and shallow. The Unified Port of San Diego maintains a dredged channel through the bay that allows shipping access. The port is a public benefit corporation and special government entity. Created in 1963 by an act of the California legislature, the port manages San Diego harbor and administers the public lands along the San Diego Bay. Both the U.S. Navy and Army Corps of Engineers have also conducted dredging (Andrea Compton, Cabrillo National Monument, written communication, August 1, 2008).

Disturbed Lands

Disturbed lands are parklands where the natural conditions and processes have been directly impacted by mining, oil and gas production, 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. Usually the NPS Disturbed Lands Restoration Program, administered by the Geologic Resources Division, does not consider lands disturbed by natural phenomena (e.g., landslides, earthquakes, floods, hurricanes, tornadoes, and fires) for restoration unless influenced by human activities.

Disturbances at Cabrillo National Monument include habitat modifications as a result of urban development. Coastal sage scrub is a rare and declining habitat type in southern California. To protect this habitat type, the National Park Service has removed nonnative species and restored areas in Cabrillo National Monument to include representative native species. This varies from smaller patches (e.g., a planter near the visitor center) to larger areas. For example, south of the old Point Loma lighthouse, the land was previously a parking lot where visitors to the lighthouse could drive up to the top of the hill. Through two major efforts, park staff has restored the area to a collection of native, coastal, sage-scrub community plants, including a portion that reflects the cultural landscape of the native vegetation that would have been present when the lighthouse was active. The National Park Service has also removed large portions of ice plant—a species that once established tends to take over and become a sprawling monoculture that kills all other species in the area (Andrea Compton, Cabrillo National Monument, written communication, August 1, 2008).

Eolian Features and Processes

When compared to the effects of coastal erosion, wind erosion is minimal at Cabrillo National Monument. Nevertheless, eolian processes have long played a role in the landscape of the Point Loma peninsula, which is composed of sandstone and covered by windblown sand. Habitats have evolved along with eolian features and processes, which continue to influence soil formation and particular species (e.g., *Chorizante orcuttiana*, an endangered annual flowering plant). Examples of eolian-influenced habitats are dunes and sand deposition in the intertidal zone. Particular locations of eolian features include dunes on the bayside and coastal dune habitat on Navy land.

Hillslope Features and Processes

Quaternary deposits at Cabrillo include gravity-deposited colluvium, which are the thickest and most aerially extensive deposits in the national monument. Colluvium mantles many marine terraces. According to Abbott and Rockwell (2004), under the right conditions these deposits can reach tens of feet thick, for example at the

bases of ancient, abandoned sea cliffs. At Point Loma, colluvium also accumulates at the base of road cuts and near the scarps of old landslides. Some of the landslide deposits at Cabrillo are fairly large and include both bedrock and surficial material. In 2005 two large slides destroyed sections of the Bayside Trail. Most landslides are located on the east side of the peninsula; the west side is more stable. During the field trip, participants noted rockfall deposits along the Point Loma cliffs; however, access to the areas below the cliffs is limited and, therefore, not a great safety concern (Stephanie O'Meara, Colorado State University, field-trip notes, August 12, 2008). Multiple episodes of colluvium indicate repeated hillslope movement at the national monument. Maps by the California Geological Survey describe and show colluvial deposits (e.g., "alluvium and slope wash" of Kennedy [1975]). Other slope movement includes slumps and soil creep, as well as unstable anthropogenic fill. Rainfall events accelerate movement and create rilling on colluvial deposits, especially artificial fill.

Marine Features and Processes

Of particular significance for determining the climatic, paleogeographic, and tectonic history of coastal California are marine terraces, which occur on both sides of the Point Loma peninsula. New, high-precision uranium-series dating of coral reefs coupled with molluscan faunal data from marine terraces have yielded further information about the timing and warmth of the last interglacial sea-level highstand (Muhs et al. 2002), potentially shedding light on the likely duration of the present interglacial period.

Marine terraces are uplifted, abandoned strips of coastline, formed in the surf zone and sublittoral zone, mantled by marine sediments and fossils, which in turn are usually overlain by terrestrial sediments. A series of 16 marine terraces and associated landforms and sedimentary deposits occurs off the coast of San Diego (Kern and Rockwell 1992). Marine terraces serve as the substrate for tidal pools, kelp forests, and reefs at the national monument. Uranium-series dating by Ku and Kern (1974) shows that one terrace level (i.e., the Nestor Terrace) in the San Diego area formed about 120,000 years ago. More recent studies have found that the Nestor terrace contains fossils of both the 120,000-year-old high sea stand and the ~100,000-year-old high sea stand (Muhs et al. 2002). During the field trip, participants noted the 80,000-year-old Bird Rock terrace exposed in a tide pool and the 900,000-year-old Linda Vista terrace exposed higher up on the slopes in Cabrillo (Stephanie O'Meara, Colorado State University, field-trip notes, August 12, 2008). These terraces occupy the highest topographic position; much of San Diego is built on this oldest terrace level.

Paleontological Resources

The three rock units at the monument all contain fossils (from youngest to oldest):

- Bay Point Formation (Pleistocene)—gastropods, bivalves, coral, barnacle, a crab claw, and trace fossils such as burrows
- Cabrillo Formation (Late Cretaceous)—shark tooth, bryozoans, oysters, and other bivalves
- Point Loma Formation (Late Cretaceous)—foraminifera, mollusks, coccoliths, plant fragments including a fossil cycad leaf, ammonites, bivalves, gastropods, clam borings and other trace fossils such as horizontal burrows. Field-trip participants also noted baculites in the Point Loma Formation (Stephanie O'Meara, Colorado State University, field-trip notes, August 12, 2008).

In addition the Nestor terrace (Pleistocene) has a rich fossil assemblage (Kern 1977).

In 2003, Alison Koch and Vince Santucci completed a preliminary inventory of paleontological resources for the Mediterranean Coast Network, including Cabrillo National Monument. National Park Service employees can access the report at <http://classicinside.nps.gov/documents/MECN-paleo-inventory.pdf>.

Notable for management is that many of these fossil resources are eroding out of the cliffs at Cabrillo National Monument. However, resource managers cannot provide much protection because these fossils are

transported away by coastal processes almost as soon as they erode out of the cliffs (Stephanie O'Meara, Colorado State University, field-trip notes, August 12, 2008).

North of the monument boundary, investigators have found large ammonites with attached thorny epibiont oysters and a partial tooth of a mosasaur in the Point Loma Formation. In addition, scoping participants mentioned a dinosaur fossil (*Anklyosaurus*) having been found in the Point Loma Formation at the nearby Palomar Airport.

Seismic Features and Processes

Cabrillo National Monument is situated in a tectonically active area. A 1-km- (0.6-mi-) wide fault zone—the Rose Canyon Fault—lies east of the national monument in San Diego. This zone includes north-to-northwest trending right-lateral strike-slip faults with appreciable (lateral) offset. Various strands of the Rose Canyon Fault zone, such as the Silver Strand Fault, dissect the Point Loma peninsula. The restraining bend of the Rose Canyon Fault explains local structure, including a broad syncline between the national monument and La Jolla (Heather Stanton, Colorado State University, field-trip notes, August 12, 2008). The submarine fan deposits from Point Loma to La Jolla show synclinal folding.

According to Abbott and Rockwell (2004), San Diego owes much of its beauty to the Rose Canyon Fault, which is responsible for the uplift of Mt. Soledad and the rocky coastline of La Jolla and the subsidence of San Diego and Mission bays. The fault system that fractures Point Loma has interpretive and educational significance, with groups of teachers and students often taking field trips here.

A better understanding of faulting and related seismic activity is needed to inform future development on the peninsula and parklands. The faults underlying the bay appear to be inactive; nevertheless, the potential for tsunami seems probable. Investigators need more information in order to make predictions and determine how much of San Diego would be inundated during a tsunami, however.

Streams and Seeps

The streams at Cabrillo National Monument are ephemeral but over time have cut deep trenches. Heavy rainfall events create short-lived waterfalls. Fluvial deposits include clasts of granitic and volcanic rocks. The Bayside Trail—originally a dirt military road (“Sylvester Road”) used during World War I and II—was built on fairly steep slopes. This road, now trail, experiences seasonal seeps in the winter and spring following rainfall. Some plant species (e.g., ferns), either parallel to the road or emerging from the cutbanks are indicative of conditions where water is present for longer periods (Andrea Compton, Cabrillo National Monument, written communication, August 1, 2008).

Unique Geologic Resources

Unique geologic resources include natural features mentioned in a unit’s enabling legislation, features of widespread geologic importance, geologic resources of interest to visitors, and geologic features worthy of interpretation. The GRE Program also considers type localities and age dates (see “Marine Features and Processes” section) as unique geologic resources. At Cabrillo National Monument, unique geologic features include the type sections of the Point Loma and Cabrillo formations. The type locality of the Point Loma Formation is at the tip of Point Loma; the type locality of the Cabrillo Formations occurs 250 m (~75 ft) east of the new Point Loma lighthouse.

A distinctive feature discussed during scoping and the field trip is the “round boulders” that are scattered along the hillslopes, coastline, and tidal pool areas. Derived from the Santiago Peak Volcanics (125 million years old), east and south of the peninsula, these boulders were transported here and deposited with the younger Cretaceous, submarine-fan deposits as the fan prograded (Stephanie O'Meara, Colorado State University, field-trip notes, August 12, 2008).

Iron pisoliths (or nodules) are another distinctive feature. These nearly spherical “concretions” are around 6 to 12 mm (0.25 to 0.5 in) in diameter and form slippery accumulations on slopes. Though scoping participants thought that the genesis was unknown, Abbott and Rockwell (2004) provide the following explanation, originally proposed by Johnson (1972):

Pisoliths are believed to have formed primarily under conifers during the Pleistocene, when it was cooler and rainfall was higher than today. Thus, all the Point Loma localities that still have these types of soils [thick, sandy eolian deposits with a shallow subsurface horizon that is commonly loaded with small sandstone spheres that are cemented with iron] are relics from the Pleistocene, when pine trees were far more extensive along the coast and conditions were more similar to those of central California today (p. 24).

Recent studies suggest that the iron in the nodules is actively precipitated by fungi (Schulz 2008) similar to the process that forms desert varnish.

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Table 2. Scoping Participants for Cabrillo National Monument

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*Participated in field trip on August 8, 2008.