National Park Service
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Natural Resource Stewardship and Science

Channel Islands National Park

Paleontological Resource Inventory (Public Version)

Natural Resource Report NPS/CHIS/NRR—2020/2171

ON THE COVER

A cast of the Rockwell mammoth on display at The Mammoth Site of Hot Springs in South Dakota. The Rockwell mammoth is a 90% complete skeleton of an aged male pygmy mammoth, excavated in 1994 from Santa Rosa Island, Channel Islands National Park (CHIS). The discovery of this specimen was important for renewing interest in the paleontology of CHIS. Other casts of this specimen can be viewed at the Santa Barbara Museum of Natural History in Santa Barbara, California and the Robert J. Lagomarsino Visitor Center (CHIS) in Ventura, California. The original bones are reposited at the Santa Barbara Museum of Natural History, which acts as the repository for CHIS. Photo by Justin Tweet (NPS).

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This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Executive Summary

Channel Island National Park (CHIS), incorporating five islands off the coast of southern California (Anacapa Island, San Miguel Island, Santa Barbara Island, Santa Cruz Island, and Santa Rosa Island), has an outstanding paleontological record. The park has significant fossils dating from the Late Cretaceous to the Holocene, representing organisms of the sea, the land, and the air. Highlights include: the famous pygmy mammoths that inhabited the conjoined northern islands during the late Pleistocene; the best fossil avifauna of any National Park Service (NPS) unit; intertwined paleontological and cultural records extending into the latest Pleistocene, including Arlington Man, the oldest well-dated human known from North America; calichified “fossil forests”; records of Miocene desmostylians and sirenians, unusual sea mammals; abundant Pleistocene mollusks illustrating changes in sea level and ocean temperature; one of the most thoroughly studied records of microfossils in the NPS; and type specimens for 23 fossil taxa.

Paleontological research on the islands of CHIS began in the second half of the 19th century. The first discovery of a mammoth specimen was reported in 1873. Research can be divided into four periods: 1) the few early reports from the 19th century; 2) a sustained burst of activity in the 1920s and 1930s; 3) a second burst from the 1950s into the 1970s; and 4) the modern period of activity, symbolically opened with the 1994 discovery of a nearly complete pygmy mammoth skeleton on Santa Rosa Island. The work associated with this paleontological resource inventory may be considered the beginning of a fifth period. Fossils were specifically mentioned in the 1938 proclamation establishing what was then Channel Islands National Monument, making CHIS one of 18 NPS areas for which paleontological resources are referenced in the enabling legislation.

Each of the five islands of CHIS has distinct paleontological and geological records, each has some kind of fossil resources, and almost all of the sedimentary formations on the islands are fossiliferous within CHIS. Anacapa Island and Santa Barbara Island, the two smallest islands, are primarily composed of Miocene volcanic rocks interfingered with small quantities of sedimentary rock and covered with a veneer of Quaternary sediments. Santa Barbara stands apart from Anacapa because it was never part of Santarosae, the landmass that existed at times in the Pleistocene when sea level was low enough that the four northern islands were connected. San Miguel Island, Santa Cruz Island, and Santa Rosa Island have more complex geologic histories. Of these three islands, San Miguel Island has relatively simple geologic structure and few formations. Santa Cruz Island has the most varied geology of the islands, as well as the longest rock record exposed at the surface, beginning with Jurassic metamorphic and intrusive igneous rocks.

The Channel Islands have been uplifted and faulted in a complex 20-million-year-long geologic episode tied to the collision of the North American and Pacific Places, the initiation of the San Andreas fault system, and the 90° clockwise rotation of the Transverse Ranges, of which the northern Channel Islands are the westernmost part. Widespread volcanic activity from about 19 to 14 million years ago is evidenced by the igneous rocks found on each island.

For most of this time the lands which are now part of the islands were submerged, as evidenced by the presence of abundant marine fossils. In situ terrestrial fossils are only definitely known from the

Quaternary, when uplift and lower sea levels allowed the development of a terrestrial flora and fauna across Santarosae. The terrestrial vertebrate fauna was of low diversity, including a few amphibians, lizards, snakes, small mammals, and mammoths. Mammoths appear to have been the only large animal that was able to make the journey to Santarosae and establish a successful breeding population, dwarfing over time in response to factors such as the restricted land area and lack of predation. A great number of bird species were able to reach Santarosae, with several seabirds forming large breeding colonies. The end of the Pleistocene brought warmer temperatures, a higher sea level, and decreasing land area, as well as a new large and predatory mammal: humans. Mammoths went extinct at approximately the same time as the first evidence of humans (around 13,000 years ago), raising the possibility that humans contributed to their extinction. Humans also changed other aspects of the islands, fishing extensively offshore and probably being responsible for the introduction of animals such as foxes, skunks, and new populations of mainland deer mice. Beginning with the end-Pleistocene arrival of humans, the paleontology of CHIS is deeply intertwined with the park's cultural record.

Microfossils are doubtless the most abundant fossils of CHIS, although they are overshadowed in comparison with other kinds of fossils due to their microscopic nature and the relative challenges of studying them. Mollusks, especially bivalves and gastropods, are the most abundant and specious macroscopic fossils of CHIS. They have been used for paleoenvironmental and paleoclimatological reconstructions, and for relative dating. Plant fossils are mostly limited to the Quaternary. Calichified roots, stems, and trunks are one of the signature features of San Miguel Island and are also found on Santa Cruz Island and Santa Rosa Island, and a small paleoflora was described from southwestern Santa Cruz Island in 1930. More recently, spores and pollen have been described from several sites, showing changes in the terrestrial environment over the past 12,000 years.

Vertebrates are also best known from the Quaternary, although there are significant marine mammal fossils from the Miocene of Santa Cruz Island (a desmostylian) and Santa Rosa Island (sirenians). The most famous fossil organism of CHIS is the pygmy mammoth, *Mammuthus exilis*. This species of elephantid is known from the three largest islands and represents a population much reduced in body size compared to mainland mammoth, averaging 750 kg (1,750 lb) and 1.72 m (5.64 ft) tall at the shoulder. Mammoths were one of the few terrestrial vertebrates to reach CHIS, which was otherwise populated by a number of bird species. Relatively few trace fossils have been reported from CHIS, and are probably more abundant than presently known.

CHIS maintains its paleontological collections at the Santa Barbara Museum of Natural History. Five other institutions have substantial collections of fossils from the islands (California Academy of Sciences, Natural History Museum of Los Angeles County, San Diego Natural History Museum, University of California Museum of Paleontology, and University of California, Santa Barbara), and smaller collections are held by several other institutions. The park has made significant efforts to include paleontological resources in interpretive and educational material, which is particularly important here due to the logistical challenges involved with visiting the islands. These challenges also mean that monitoring and managing paleontological resources require creative solutions. Toward this end, a variety of recommendations are included.

Acknowledgments

Many people have assisted us with the creation of this report. From Channel Islands National Park (CHIS) itself, Yvonne Menard provided extensive information on paleontological resource interpretation and education at CHIS, and Yvonne, Lauren Boross, and Monique Navarro reviewed the interpretation section. Tim Connors of the NPS Geologic Resources Division prepared the maps for the report, as well as contributing a program review. Don Morris (retired CHIS archeologist) showed us historically significant sites on Santa Rosa Island, reviewed drafts of the manuscript, and gave an oral interview on paleontological work on the island and his role in it. Allen Calvert (Mojave Desert Inventory & Monitoring Network) served as peer review coordinator. We would also like to recognize former CHIS staff Kate Faulkner (Chief of Natural Resources) and Ann Huston (Chief of Cultural Resources) for their contributions to the chapter on CHIS paleontological resources published as part of the 2012 Mediterranean Coast Inventory & Monitoring Network paleontological resource summary, which served as the nucleus of this inventory.

Many people have generously answered queries about fossil occurrences and specimens, or provided other assistance. We would like to recognize: Paul Callomon of the Academy of Natural Sciences of Drexel University; Maricela Abarca and Christine Garcia of the California Academy of Sciences; Darci Moore of the California State Mining and Mineral Museum; Jason Irving of Ediacara Conservation Park; Gwenn Gallenstein of the Flagstaff Area National Monuments; Jim Mead and Justin Wilkins of The Mammoth Site of Hot Springs; Samuel McLeod and Vanessa Rhue (now at Yale Peabody) of the Natural History Museum of Los Angeles County; David Dewey and Scott Meyler of The Nature Conservancy; R. Scott Anderson and Anne Miller of Northern Arizona University; Paul Collins, John Johnson, and Terri Sheridan of the Santa Barbara Museum of Natural History; Lorna Kirwan and Susan McElrath of the University of California Bancroft Library; Daniel Muhs, Jeff Pigati, and Kathleen Springer of the U.S. Geological Survey; Brent Phillips, Susannah Porter, Bruce Tiffney, and Andy Wyss of University of California, Santa Barbara; Kim Beckwith of the Western Archeological and Conservation Center; David Bustos of White Sands National Park; and Susan Butts and Jessica Utrup of Yale University's Peabody Museum of Natural History. We thank Nancy Stamm and Dave Soller from the U.S. Geological Survey for providing access to the USGS's Examine & Report archives, and their assistance with using these files. We also thank Steve Junak and Randy Wright of the Santa Barbara Botanical Garden for Figures 3, 18, 20, and 28. R. Scott Anderson (Northern Arizona University) and Daniel Muhs (U.S. Geological Survey) provided reviews.

It is a lamentable coincidence that important figures in the geology or paleontology of a park frequently seem to pass away not long before we begin a park paleontological inventory, and this CHIS inventory is no exception. In this case, however, three such signature figures contributed input to the CHIS park paleontological summary published in 2012, and so their personal influences carry on. They were Larry Agenbroad (Mammoth Site of Hot Springs), Daniel Guthrie (Claremont McKenna College), and Donald Johnson (University of Illinois).

We would also like to thank the American Geosciences Institute for their assistance with Justin's position.

Dedication

We are proud to dedicate the Channel Islands National Park Paleontological Resource Inventory to Don Morris and Larry Agenbroad, significant figures in the story of CHIS paleontology since the mid-1980s. Their roles in CHIS paleontological history are closely linked, so it made perfect sense to include both of them. Larry regrettably passed away in 2014, but Don joined our group on Santa Rosa Island in June 2019 to show us important localities and describe his experiences, which culminated in an informative and entertaining oral history interview.

Don, who was the CHIS archeologist from 1985 until his retirement in 2001, worked at a variety of parks in the western United States for his entire career, beginning as a seasonal at Mesa Verde National Park in 1959. His experience at CHIS began in 1982, when he was part of a group of NPS staff who came to Santa Rosa Island to assess the island's resources. At the time, he was mostly focused on the substantial archeological resources of the island, being under the impression that the pygmy mammoths were "a known story". After becoming the park archeologist in 1985, he occasionally encountered and collected mammoth material, including with Daniel Guthrie, then in the midst of his work with fossil birds and small mammals from the islands.

This all changed in June 1994, when Don was working on Santa Rosa Island with a small group including geologist Tom Rockwell of San Diego State University. Rockwell was interested in the Quaternary stratigraphy and sea terraces, and asked Don about a good place to see the terraces. Don suggested an area near a sea cave he wanted to inspect for archeological resources. The cave proved to be barren, but Tom found the nearly complete pygmy mammoth specimen now known informally as the Rockwell mammoth in his honor. Back on the mainland, Don made inquiries about finding a paleontologist to consult with concerning this find. Several people suggested Larry Agenbroad, who Don knew of because of his work at Murray Springs, Arizona. Don recalls calling Larry about the fossil mammoth discovery on a Tuesday, and having Larry arrive at his house ready to go Thursday night. Larry was already interested in doing work on the islands, so the situation was ideal.

The excavation of the Rockwell mammoth in 1994 by Larry, Don, and others was the beginning of a long and fruitful relationship between CHIS and the Mammoth Site of Hot Springs that has gone on through many field seasons. The most recent major project has been the collection and preparation of the Larramendy mammoth skull, found on Santa Rosa Island in 2014 and excavated in 2016. Through the field work of Don, Larry, and others, hundreds of mammoth localities have been documented, and the wealth of new specimens has greatly improved our understanding of the biology and evolution of these island-bound animals. Don and Larry became good friends, with Don continuing to work with Larry and the Mammoth Site staff after his retirement.

Larry Agenbroad (left) and Don Morris (right) on Santa Rosa Island, circa 2010 (WANDA AGENBROAD?).

Introduction

Channel Islands National Park (CHIS) protects five of California's eight Channel Islands and the surrounding ocean for a distance of 1.8 km (1 nautical mile) (Figure 1). The four northern islands of CHIS are aligned east–west in a line about 100 km (60 mi) long, separated from the mainland by the Santa Barbara Channel. From west to east the northern Channel Islands are San Miguel Island, Santa Rosa Island, Santa Cruz Island, and Anacapa Island. Nearby landmarks on the mainland include Port Hueneme in Oxnard, which is approximately 20 km (12 mi) northeast of Anacapa Island; the CHIS visitor center in Ventura, 27 km (17 mi) northeast of Anacapa Island; Santa Barbara, 37 km (23 mi) north of Santa Cruz Island; and Point Conception, 41 km (26 mi) north of San Miguel Island. The fifth island of CHIS, Santa Barbara Island, is approximately 66 km (41 mi) southeast of Anacapa Island, the nearest of the four northern islands. Santa Barbara Island is also approximately 64 km (40 mi) southwest of Palos Verdes Point.

The islands of CHIS are divided between two of California's counties: San Miguel Island, Santa Barbara Island, Santa Cruz Island, and Santa Rosa Island are part of Santa Barbara County, and Anacapa Island is part of Ventura County. The three Channel Islands not included in CHIS are San Clemente Island, San Nicolas Island, and Santa Catalina Island. Together with Santa Barbara Island, they are grouped as the southern Channel Islands. San Nicolas Island is about 45 km (28 mi) southwest of Santa Barbara Island and 77 km (48 mi) south of Santa Cruz Island. Santa Catalina Island is 39 km (24 mi) east of Santa Barbara Island, and San Clemente Island is 62 km (39 mi) southeast of Santa Barbara Island, due south of Santa Catalina Island. San Nicolas Island is also part of Ventura County, while San Clemente Island and Santa Catalina Island are included in Los Angeles County.

CHIS includes a variety of natural and cultural resources ranging from endemic organisms and rookeries of sea birds and sea lions to hundreds of archeological sites as old as the late Pleistocene. Paleontological resources are abundant and can be found on all five islands. They range in age from the Cretaceous to the Holocene, and include examples of many different categories of marine and terrestrial life, headlined by the pygmy mammoth *Mammuthus exilis*. CHIS was originally proclaimed as a national monument on April 26, 1938, at which time it included only Anacapa Island and Santa Barbara Island. It was designated a Biosphere Reserve in 1976, and redesignated a national park March 5, 1980, when it was expanded to include San Miguel, Santa Cruz, and Santa Rosa islands. CHIS's boundaries changed June 10, 1949; May 15, 1978; and October 25, 1978. Today, it encompasses 100,993.75 ha (249,561 acres). The National Park Service (NPS) owns Anacapa Island, Santa Barbara Island, Santa Rosa Island, and the eastern 24% of Santa Cruz Island; it administers Santa Cruz Island in partnership with The Nature Conservancy, which owns the western 76% of the island, and administers San Miguel Island under an agreement with the U.S. Navy. This report will consider each of the five islands as a whole, without divisions. For reference, the boundary between lands of The Nature Conservancy and National Park Service on Santa Cruz Island runs across the "neck" of the island, from Prisoners Harbor in the north to Valley Anchorage in the south, but is not a straight line (Figure 1).

Figure 1. Geography of Channel Islands National Park (NPS map).

Significance of Paleontological Resources at CHIS

Paleontological resources, or fossils, are any evidence of past life preserved in geologic context. CHIS is one of just 18 NPS units that have paleontological resources recognized in the legislation that established them, and this recognition is well-warranted. Almost all of the sedimentary formations of CHIS are known to be fossiliferous, and are sometimes abundantly fossiliferous. Unsurprisingly, the islands have rich marine fossil records (particularly of mollusks and microfossils), but they also have noteworthy Pleistocene and Holocene terrestrial fossil records, highlighted by "fossil forests" and pygmy mammoths. Because of the scarcity of burrowing animals, the Quaternary records are also notably undisturbed. Many Holocene fossils have been found in cultural contexts, such as shell middens, and there are substantial museum collections of CHIS fossils. San Miguel Island and to a lesser extent Anacapa, Santa Barbara, and Santa Rosa islands have outstanding late Quaternary fossils of birds, collectively representing the best such record in the National Park Service and one of the most significant late Quaternary avifaunas of North America. The late Quaternary fossils are also intertwined with the extensive archeological record of the islands, providing a long-term record of floral and faunal responses to the appearance and establishment of humans just before the end of the Pleistocene. These fossil records are useful for management, showing which organisms were present at various times and under various climatic and other conditions in the recent past. As a whole, the paleontological record of the islands is evidence of the significant geologic and tectonic changes that have taken place since the middle Mesozoic, approximately 160 million years ago, and continuing to the changes in sea level and island land area over the past few thousand years.

Purpose and Need

The NPS is required to manage its lands and resources in accordance with federal laws, regulations, management policies, guidelines, and scientific principles. Those authorities and guidance directly applicable to paleontological resources are cited below. Paleontological resource inventories have been developed by the NPS in order to compile information regarding the scope, significance, distribution, and management issues associated with fossil resources present within parks. This information is intended to increase awareness of park fossils and paleontological issues in order to inform management decisions and actions that comply with these laws, directives, and policies. Paleontological resource management faces particular challenges due to the non-renewable nature of fossils and the loss of data when fossils are separated from their geologic context. See Appendix D for additional information on applicable laws and legislation.

Project Objectives

This park-focused paleontological resource inventory project was initiated to provide information to CHIS staff for use in formulating management activities and procedures that would enable compliance with related laws, regulations, policy, and management guidelines. Additionally, this project will facilitate future research and resource management associated with the paleontological resources at CHIS. Methods and tasks addressed in this inventory report include: locating, identifying, and documenting paleontological resource localities through field reconnaissance using photography, GPS data, and standardized forms; relocating and assessing historical localities; assessing collections of CHIS fossils maintained within park collections and in outside repositories;

and a thorough search for relevant publications, unpublished geologic notes, and outside fossil collections from CHIS. To facilitate this project, a field visit to significant localities on Santa Rosa Island was held June 28–30, 2019, followed by a paleontological resource scoping session July 1.

History of Paleontological Work at CHIS

The history of paleontological work at CHIS can be broadly divided into four periods: 1) the few early reports from the 19th century; 2) the first sustained burst of activity, resulting in a number of publications from the late 1920s through the 1930s; 3) a second burst from the 1950s into the 1970s; and 4) the modern period of activity, beginning in the 1990s. The work associated with this paleontological resource inventory for CHIS and preparation of this report may be considered the beginning of a fifth period of fossil-focused work for the park.

Paleontological studies at CHIS began slowly. The first report of fossils from the islands now included in the park administrative boundaries is frequently given as Stearns (1873), a brief paraphrase of comments made at a meeting of the California Academy of Sciences on September 1, 1873 concerning a mammoth tooth recovered from Santa Rosa Island by W. G. Blunt. There is actually a slightly older notice concerning this specimen: a mention of the specimen being given to the Academy in April 1873, mistakenly reported as from Santa Barbara Island (Anonymous 1873). Although the collection date is sometimes placed in the 1850s (Orr 1968; Roth 1996a; Agenbroad 1999a, 2001), Blunt reported collecting it in 1871 (Voy 1890–1893a). According to Stearns (1873), Blunt had located a tooth and a tusk. The tusk crumbled when he tried to collect it, but the tooth survived and was presented to the California Academy of Sciences (CAS: San Francisco, California). Unfortunately, this tooth does not appear in a list of Channel Islands fossils currently reposited at CAS (C. Garcia, collections manager of geology, California Academy of Sciences, pers. comm., August 2019); presumably it was lost along with almost all of the early CAS collections in the 1906 San Francisco earthquake and ensuing fires. Other notable Santa Rosa Island fossils were first reported a few years later (Bowers 1878), including what can be recognized as tree casts and Pleistocene examples of the abundant terrestrial snail *Helminthoglypta ayresiana*.

There is an even earlier record of fossils from CHIS, but there are few details. Naturalist James Graham Cooper visited the four southern islands and Santa Cruz Island in the early 1860s and submitted a manuscript to California state geologist Josiah Dwight Whitney (Cooper 1863). Whitney in turn adapted most of this for a short description of the geology of these islands (Whitney 1865). On Santa Barbara Island, Cooper observed fossil shells on a "raised beach…above the sea". Cooper also recorded that a "Dr. J. B. Shaw" had told him that fossiliferous rocks were present on Santa Cruz Island. Cooper himself did not find any in a brief investigation in the Prisoners Harbor area of the island; in hindsight, this area has igneous bedrock (Santa Cruz Island Volcanics) and would be an unlikely place to find fossils. Watson Andrews Goodyear, who spent a longer time examining the island's geology in 1889, raised this point when briefly dismissing the value of the Santa Cruz Island information in Whitney's article (Goodyear 1890).

Goodyear's own observations on Santa Cruz Island turned up little in the way of fossils, apart from a shell seen in white rock and impressions he thought resembled leaves or seaweed, but which were too indistinct for him to be certain. Interestingly, examples of these impressions were present in stones quarried on the island and used to face the corners of a house. In paleontological terms, Goodyear's report is more famous today for his firm belief that the islands were never connected to the mainland, and his suspicion that the report of mammoth bones on Santa Rosa Island was erroneous.

The naturalist Lorenzo Gordin Yates, a founder of the Santa Barbara Natural History Society, collected many biological, archeological, and paleontological specimens from the northern Channel Islands in the last quarter of the 19th century. His paleontological collections from Santa Rosa Island included several taxa of mollusks which appear to be from the productive Rincon/Vaqueros interval (e.g., *Turritella inezana*), as well as the lower jaw of a young seal and four examples of what he thought might be peccary tusks (Yates 1886). Given that no one else has reported peccary remains from the island, it is possible that Yates actually had fragments of mammoth tusks. These finds and additional mammoth bones recovered by Charles D. Voy for the state university at Berkeley were summarized in Dall and Harris (1892).

Voy prepared manuscripts for the California State Mining Bureau on Santa Rosa and San Miguel islands, which included discussions of their geology and paleontology (Voy 1890–1893a, 1890–1893b). Publication was cancelled following a statement by Governor Henry Markham which criticized printing costs and the length and content of some recent and planned publications (see Yale 1893 for additional details, including specific comments on Voy's submissions), and the manuscripts were long thought to be lost (e.g., Hill's note attached to Johnson 1967). However, handwritten copies of the manuscripts do exist in the Yates archives in the Bancroft Library at the University of California, Berkeley and were obtained as part of this inventory. Among the contents of these drafts is what may be the oldest known photograph of mammoth fossils from CHIS (Figure 2). Voy also documented the "caliche forests" of San Miguel Island, *Helminthoglypta ayresiana* shells, and "Pliocene" marine fossils of the two islands. Yates later reused about a third of Voy's plates for a serialized publication on the prehistory of California (Yates 1902–1905), including the mammoth plate and plates illustrating marine shell fossils, land snail fossils, and the "caliche forests".

Voy reported the presence of large and small mammoth bones, which he attributed to as many as three species, so it seems likely that he encountered both Columbian mammoth and pygmy mammoth specimens. Most of the specimens he attempted to collect crumbled when exposed to the air, but he did recover a few specimens, which he deposited in the "Museum of the State Mining Bureau" (Voy 1890–1893a). These, a few pieces of calichified vegetation, and a group of marine fossils from both islands are recorded by the California State Mining Bureau (1899) and can be considered Voy's collections. The California State Mining and Mineral Museum transferred its fossil collections to the California Academy of Sciences mid-century (D. Moore, Curator II, California State Mining and Mineral Museum, pers. comm., November 2019), and at least some of Voy's specimens are still extant at the CAS (C. Garcia, pers. comm., November 2019).

Figure 2. C. D. Voy's proposed plate illustrating Santa Rosa Island mammoth fossils (Voy 1890–1893a). The plate, but not the caption, was reused by Voy's colleague Yates (Yates 1902–1905:2(9):plate XI).

Apart from Yates's series and Arnold (1906), which named the Miocene bivalve *Pecten miguelensis* (now *Lyropecten miguelensis*) from San Miguel Island, there are no substantial paleontological reports from CHIS until the 1920s. In the late 1920s, Dorothy Irma Cooke of the Santa Barbara Museum of Natural History found a mammoth tusk. This find eventually led to paleontologists Chester Stock and E. L. Furlong of Caltech collecting more fossils from the island in 1927 and 1928 and publishing them as *Elephas exilis* in Stock and Furlong (1928) (now *Mammuthus exilis*) (Roth 1996a). At approximately the same time, Kew (1927) published the first substantial geological description of any of the Channel Islands (Santa Rosa Island), and Hertlein (1928) made the first detailed description of the paleontology of San Miguel Island and Santa Rosa Island, naming several Miocene mollusks. More than a dozen additional publications on the paleontology and geology of CHIS were produced during the next decade. Bedrock geological descriptions for several of the islands were published over the next few years: Santa Cruz Island (Rand 1931, 1933; Bremner 1932), San Miguel Island (Bremner 1933), and Santa Barbara Island (Kemnitzer 1933). Some publications described notable taxa, including the "giant deer mouse" *Peromyscus nesodytes* (Wilson 1936) and the land snail *Helminthoglypta ayresiana lesteri* (Cockerell 1938a; now regarded as simply *H. ayresiana*). Other publications included Chaney and Mason (1930) on the Pleistocene plants of Santa Cruz Island (the publication year is also given as 1934, which appears to be due to the Carnegie Institution of Washington publishing items both as individual papers from a volume and within volumes); Loel and Corey (1932) on the fauna of the Vaqueros Formation on several islands; Stock (1935) on the mammoths; a series of additional publications by Cockerell (1937, 1938b, 1938c, 1939, 1940); and Grant and Hertlein (1938), which described new echinoids from Santa Rosa Island.

President Franklin D. Roosevelt recognized the presence of mammoth and tree fossils in the northern Channel Islands in his 1938 proclamation of Channel Islands National Monument:

> *"WHEREAS certain public islands lying off the coast of Southern California contain fossils of Pleistocene elephants and ancient trees, and furnish noteworthy examples of ancient volcanism, deposition, and active sea erosion, and have situated thereon various other objects of geological and scientific interest..."* (Pres Proclamation #2281 (1938) (52 Stat. 1541)).

It is noteworthy that at the time, the monument included only Anacapa Island and Santa Barbara Island, which are the only two islands of CHIS not to have produced "fossils of Pleistocene elephants and ancient trees". As noted by Muhs (2018), the description of the islands is taken from Cockerell (1938b), which had filtered through internal correspondence in the lead-up to the proclamation. Cockerell, a naturalist of wide-ranging interests including paleontology, was a crucial figure for changing NPS attitudes regarding the creation of Channel Islands National Monument (Muhs 2018). The mention of the fossils from the other islands in the 1938 proclamation is not entirely incongruous, because there was internal interest in the future acquisition of other islands, with discussions held concerning San Miguel, San Nicolas, and Santa Cruz islands (Muhs 2018). It would not be until the 1980 expansion and redesignation as Channel Islands National Park that CHIS would include the three islands that feature the fossils mentioned in the 1938 proclamation.

There were few paleontology-focused publications during the 1940s and 1950s. Among them were an initial description of fossil birds found during the pygmy mammoth excavations of the late 1920s (Howard 1944), a short piece on the geology of Anacapa Island (Scholl 1959, followed by a longer description in Scholl 1960), and the first of Phil Orr's several publications on the late Quaternary of the islands (Orr 1956a). Orr worked for the Santa Barbara Museum of Natural History from 1938 to 1969 and spent many field seasons on Santa Rosa Island, where he collected numerous pygmy mammoth fossils for the museum. He had planned to begin exploration for mammoth fossils on the island in the early 1940s, making a flyover on December 7, 1941 and discovering on his return that Pearl Harbor had been attacked that day. The war delayed his return until 1946 (Orr 1968). Coincidentally, the attack on Pearl Harbor also interrupted paleontological investigations then being conducted on the island by a party from the Natural History Museum of Los Angeles County as part of the Channel Islands Biological Survey. The LACM party was stranded on Santa Rosa Island for several days as a result.

An archeologist by training, Orr was intrigued by the possibility that early human arrivals to the islands had hunted the mammoths to extinction, and scoured the island for evidence that could prove this hypothesis. Among these were the features he interpreted as "fire areas" made by humans cooking butchered mammoths. These features were briefly reinterpreted as localized groundwater mineralization (Cushing et al. 1986). However, they are once again seen as evidence of fires, but natural rather than anthropogenic fires: it is now recognized that fires played an important ecological role on the islands before humans arrived (Rick et al. 2012a; Pigati et al. 2014). By far his most notable find on Santa Rosa Island is Arlington Man, as of 2019 the oldest well-dated human skeletal remains found in North America. This find was announced in Orr (1962). He summarized his work in a 1968 book, "Prehistory of Santa Rosa Island".

The 1960s were a time of intense field work on the two islands then part of CHIS and on the three islands that would later be added to the park. Several descriptions of members of the significant Pleistocene avifauna of CHIS were published in the early 1960s, beginning with Miller et al. (1961) reporting the extinct flightless sea duck *Chendytes lawi* from Anacapa Island. The noted paleo-ornithologist Hildegarde Howard published on a caracara from Santa Rosa Island (Howard 1962), additional *Chendytes* remains from Anacapa Island (Howard 1964a), and an owl from Santa Rosa Island, which she named *Asio priscus* (Howard 1964b). Anacapa Island has received the least paleontological attention of the four northern Channel Islands, but the 1960s were a fertile period for paleontological research. Staff from UCLA collected fossils from West Anacapa Island in the early 1960s, providing the basis for the bird papers, descriptions of Pleistocene invertebrate fossils (Valentine and Lipps 1963; Lipps 1964), and the description of a new rodent species, *Peromyscus anyapahensis* (White 1966). UCLA crews also visited Santa Barbara Island and collected the fossils that were reported in Lipps et al. (1968). UCLA collections are now at the Natural History Museum of Los Angeles County (LACM). At the other end of the islands, archeologist Charles Rozaire and a crew from the LACM excavated on San Miguel Island from 1967 to 1968 (Guthrie 1980); among their finds was a significant fossil bird locality. In 1965 the partial skeleton of a Miocene desmostylian was collected from Santa Cruz Island; it has not been formally described, but has been mentioned in Barnes and Aranda-Manteca (1997) and Domning and Barnes (2007). Several graduate students of UC-Santa Barbara began field projects on the geology and paleontology of San Miguel, Santa Cruz, and Santa Rosa islands in the 1960s, which culminated in "Geology of the northern Channel Islands, southern California borderland" (Weaver et al. 1969a), an essential reference for consideration of these topics. Donald Johnson began publishing on the Channel Islands in the 1960s as well, including Johnson (1967) on the caliche and "caliche forests" (see Muhs 2014 for an overview of Johnson's extensive career).

The intensity of paleontological study on the islands was not as great during the 1970s and 1980s, but there were still a number of significant contributions. Another edited volume, "Aspects of the geologic history of the California continental borderland" (Howell 1976), revised and updated some of the conclusions published in Weaver et al. (1969a). One of the significant topics of discussion in this period was how mammoths arrived at the islands. Historically, mammoths were thought to have traveled there via a now-lost land bridge (e.g., Stock 1935). Participants at a 1965 symposium on the biology of the California islands were split in their acceptance of a land bridge (Philbrick 1967; Johnson 1978). Donald Johnson became the leading figure arguing that there was no geographic or geologic evidence for a land bridge, and that the mammoths could have swum to the larger late Pleistocene Santarosae (e.g., Johnson 1978, 1980, 1981; Junger and Johnson 1980; Wenner and Johnson 1980). The swimming hypothesis has been generally accepted since then, although not without some challenge (e.g., Azzaroli 1981). Publications from this period dealing with other aspects of the island mammoths include Hooijer (1976), Cushing et al. (1984), and Roth (1984). In 1980, CHIS became a national park with the addition of San Miguel Island, Santa Cruz Island, and Santa Rosa Island. The first of Daniel Guthrie's inventories of CHIS birds and other small vertebrates was published the same year, to be followed by several others over the years (Guthrie 1980, 1992, 1993, 1998, 2005; Collins et al. 2018a). Paleobotanist Daniel I. Axelrod investigated the fossil conifers of Santa Cruz Island in the 1980s (Axelrod 1983, 1986) (Figure 3). The extinct vampire bat *Desmodus stocki*, an unusual component of the CHIS Pleistocene fauna, was spotlighted in Ray et al. (1988). Another notable CHIS animal, the island fox, was discussed as a Pleistocene arrival by Collins (1991), although later research indicates a Holocene arrival (Rick et al. 2009). Additionally, Smith (1991) revisited several Miocene bivalve taxa.

Figure 3. Daniel I. Axelrod with a clump of fossil conifer cones on Santa Cruz Island, 1982. Photo by Steve Junak, courtesy of the Santa Barbara Botanic Garden.

The 1994 discovery of the Rockwell mammoth on Santa Rosa Island can be considered the symbolic beginning of a new phase of paleontological study on CHIS. A great number of publications that touch upon CHIS paleontology and geology have been made in the past quarter-century, with the

Quaternary being a particular area of focus. Listing every such publication is beyond the scope of this work, so some unique or otherwise significant examples have been selected to give an idea of the breadth of work. Not counting the avifauna inventories mentioned in the previous paragraph, several groups of small vertebrates have received special attention, including puffins (Guthrie et al. 1999), salamanders (Mead et al. 2004), Holocene dogs (Rick et al. 2008), frogs (Mead et al. 2018), and mice (Shirazi et al. 2018). The Cenozoic fossils of Santa Cruz Island were inventoried in Shapiro (1998), part of a larger volume that documented various aspects of the geology of the northern Channel Islands (Weigand 1998). The human influence on the fauna at a late Quaternary site on San Miguel Island has been discussed in Erlandson et al. (1996, 1999) and Rick et al. (2001).

NPS interest in the fire history of the islands for management purposes led to studies of the late Quaternary paleobotany in this time frame as well. Early studies in this direction include Cole and Liu (1994) on Santa Rosa Island, and Anderson (1998) on Santa Cruz Island. The paleobotany of Santa Cruz Island was revisited by Anderson et al. (2008) and Grant (2016), and pollen from Santa Rosa Island was used by Anderson et al. (2010) in their study of the island's fire history and vegetation history. Also related to fire, as discussed below under "Geologic History", Santa Rosa Island has been an important part of the Younger Dryas impact debate. A shelf of papers referring to CHIS mammoths could probably be assembled from the research of the last quarter century, with recent summaries of the state of knowledge in Agenbroad (2012) and Muhs et al. (2015). The Quaternary marine invertebrates of the islands have been documented in studies of human subsistence (Ainis et al. 2011; Erlandson et al. 2011) and island sea level histories (Muhs et al. 2014; Muhs and Groves 2018). Finally, Pigati et al. (2017) used recent finds of mammoth fossils on San Miguel Island as case studies for documenting the geology and stratigraphy of island discoveries.

Recent significant fossil discoveries include the Larramendy mammoth, discovered in 2014 and excavated in 2016; and two Miocene sirenian specimens also found on Santa Rosa Island, the better preserved of which was excavated in 2017 by paleontologists from the Santa Barbara Museum of Natural History. The sirenians illustrate the rapid erosion of the islands and the need for timely response to finds. It was not immediately possible to excavate the first specimen, and by the time that excavation could be done, this specimen had undergone significant erosion. Fortunately, a second and less weathered sirenian specimen was found nearby, in a more accessible setting as well.

With the increased interest in the paleontology of CHIS, the NPS Paleontology Program has worked to more fully document known paleontological resources. The first such summary was produced by Alison Koch and Vincent Santucci as part of a Mediterranean Coast Inventory & Monitoring Network (MEDN) paleontological resource inventory (Koch and Santucci 2003). This was revised and expanded a few years later as part of an updated MEDN paleontological resource inventory (Tweet et al. 2012). The present document is the first paleontological resource inventory devoted specifically to CHIS.

Geology Overview

Geologic History

The geologic record of CHIS, as exposed at the surface, goes back as far as the Middle Jurassic (see Appendix E for a geologic time scale), but is biased to the Cenozoic. The oldest rocks on Anacapa Island and Santa Barbara Island are Miocene, and while the geologic records on the other islands go back to the Mesozoic, their rocks were mostly deposited from the early Eocene into the late Miocene (approximately 50–15 Ma, or million years ago). All of the islands also have significant Quaternary surficial rocks and deposits. Together the islands document marine sedimentation, volcanic eruptions, and tectonic upheaval during the Cenozoic of coastal California.

The northern Channel Islands are part of the Transverse Ranges terrane (distinct block of continental crust) or block (Atwater 1998), which underwent dramatic changes in location and orientation during the Cenozoic. Paleomagnetic data indicate that the block was attached to the North American craton during the Jurassic, Cretaceous, and early Cenozoic. The paleomagnetic tracks of the block and the rest of North America do not begin to diverge until the middle Cenozoic, when the block began moving north relative to the continent (Champion et al. 1986). For the Mesozoic–early Cenozoic time frame, the future northern Channel Islands were probably near San Diego (Bartling and Abbott 1983; Atwater 1998). During the Late Cretaceous, the area including the four northern islands would have been a short distance south of San Diego, with the two areas recording the deposition of similar submarine fans. Later, during the Eocene, the block moved north far enough to juxtapose the future site of the islands with the San Diego area, resulting in the accumulation of the same type of conglomerates (Bartling and Abbott 1983; these are often known as Poway conglomerates).

The oldest exposed rocks within CHIS are found on Santa Cruz Island (Weaver 1969a), and consist of metamorphic and igneous rocks that formed from the Middle Jurassic to the Early Cretaceous. Intrusive igneous rocks named the Willows Diorite or Willows Plutonic Complex formed about 162 Ma (Mattinson and Hill 1976). At approximately the same time, a submarine volcanic pile was forming in the vicinity. This pile and its associated sediments and igneous intrusions later metamorphosed into the Santa Cruz Island Schist (Hill 1976). These two units have been interpreted as fragments of one or more island arcs (Sorensen 1985). Another igneous body, the Alamos Tonalite, intrudes the schist (Weaver 1969a). This event occurred at approximately 141 Ma (Mattinson and Hill 1976). Younger Cretaceous sedimentary rocks of marine origin are exposed on San Miguel Island (Weaver and Doerner 1969a) and have been found in cores from Santa Cruz Island (Doerner 1969; Weaver 1969b).

The best record of the Paleocene and Eocene in CHIS is found on Santa Cruz Island. Rocks of this age are also exposed on San Miguel Island and Santa Rosa Island (Dibblee 1982a). During the Paleocene, what became San Miguel Island was located in a sediment-starved marine basin, while the Santa Cruz Island area was on the continental shelf. Both areas were covered by submarine sediment fans during the Eocene (Kies and Abbott 1982). Tropical marine conditions that began during the Late Cretaceous persisted into the Eocene, then gave way to cooler water (Doerner 1969). The depth of the ocean fluctuated several times as a result of marine transgressions (sea level rise) and regressions (sea level fall). The early and middle Paleocene were marked by regressions (Bartling and Abbott 1983), and a sea level fall during the early Eocene is evidenced by the onset of coarser sedimentation (Abbott et al. 1983). Depth increased to bathyal (broadly, continental slope) (Erickson 1975) and deeper (Doerner 1969) later in the Eocene. It has been suggested that there was terrestrial deposition on Santa Rosa Island during the Oligocene based on the presence of the Sespe Formation, which is terrestrial on the mainland (Avila and Weaver 1969). Woolley (1998) interpreted the Santa Rosa Island Sespe Formation as including both terrestrial and marine rocks. Definite marine conditions prevailed for the deposition of the Vaqueros, Rincon, and Monterey formations, which were deposited in progressively deeper settings (Bandy and Kolpack 1963).

The Miocene of CHIS is marked by volcanism and plate movement that brought the northern Channel Islands close to their present location. These events were the result of long-term tectonic activity along the western margin of North America. During the subduction of oceanic crust beneath western North America in the middle Cenozoic, a portion of the subducting plate fragmented off and became a microplate (the Monterey microplate). Before it was subducted, it was captured by the Pacific plate, at approximately 30 Ma. This set off a chain of events in the numerous small continental blocks along the southwestern margin of the North American plate. The Transverse Ranges block was wrenched out of position at about 19 Ma and rotated clockwise. This rotation and associated rifting allowed the underlying asthenosphere to well up, leading to widespread volcanism; the volcanism was the source of the volcanic rocks that make up a significant portion of the bedrock of the Channel Islands and Santa Monica Mountains (Weigand et al. 2002). In the area that would become CHIS, volcanism was both subaerial and submarine (Weigand and Savage 1999). Volcanism ended by about 16 Ma (Weigand et al. 2002) and rotation ceased by approximately 12 Ma (Weigand and Savage 1993). By the time the position of the Transverse Ranges block stabilized, the block had rotated roughly 90° clockwise (Bartling and Abbott 1983), and moved a few degrees north; there is some disagreement about the magnitude of northward movement between different measurement methods, but in relative terms the block has moved north from the vicinity of San Diego (Kamerling and Luyendyk 1985). In addition, the cross-island faults on Santa Cruz and Santa Rosa islands have been interpreted as marking the boundaries of distinct fragments (i.e., that these two islands are juxtapositions of smaller tectonic units, not single units; see for example paleotectonic reconstructions in Luyendyk 1991). Following the volcanic activity, more marine sediments were deposited over the continental shelf and slope settings (Avila and Weaver 1969; Bereskin and Edwards 1969; Weaver and Doerner 1969b; Weaver and Meyer 1969). Unlike the northern Channel Islands, the southern Channel Islands, including Santa Barbara Island, are not part of the Transverse Ranges block and have not been rotated (Pinter and Sorlien 1991).

Definite Pliocene-age rocks have not been found on the islands, which are thought to have been topographic highs during that time (Weaver and Doerner 1969b; Dibblee 1982a). Strontium isotope ratios indicate that the islands have been emergent for much of the Pleistocene: Santa Cruz Island and Santa Rosa Island have been emergent since at least 2 Ma, and Anacapa Island and Santa Barbara Island may have been emergent by around 1.6 Ma (D. Muhs, U.S. Geological Survey, pers. comm., February 2012). The islands have been gradually rising throughout the Pleistocene. Their maximum subaerial exposure was probably during the sea level lowstand at the end of the

Pleistocene. At this time, the four northern Channel Islands were connected as part of a larger landmass known as Santarosae, after Orr (1968) (sometimes written as Santa Rosae) (Johnson 1978) (Figure 4). For many years, it was thought that the islands had been a peninsula of the mainland at some point during the Pleistocene, to account for the presence of mammoths (see for example Stock 1935 or Azzaroli 1981), but this hypothesis has been discredited based on the submarine geography and geology of the area (Johnson 1978; Junger and Johnson 1980; Wenner and Johnson 1980) and the previously unappreciated swimming capabilities of elephants (Johnson 1978, 1980). Sea level was as much as 100–110 m (330–360 ft) lower than present in the Channel Islands area at the last glacial maximum, about 20,000 years ago (Reeder-Myers et al. 2015). It should be noted that sea level varied greatly during the Pleistocene; for example, marine terraces on San Miguel Island and Santa Rosa Island indicate that during the previous interglacial, about 120,000 years ago, these two islands looked very similar to the present, just slightly smaller (Muhs et al. 2015). Because of rising sea levels during the Holocene, there are paleontological and archeological resources on now-submerged former coastal areas of the islands, and they occasionally wash up on the islands (Orr 1956b). The islands' dunes formed during glacial periods, when sand-sized carbonate debris (consisting of skeletal fragments of marine organisms) from the islands' shelves was made available by lower sea levels (Muhs et al. 2018). Coastal California may have been an ice-age refugium, with a stable long-term Mediterranean climate (Johnson 1977).

Recently, sediment from CHIS was part of a series of studies attempting to determine if there was an extraterrestrial impact that triggered the Younger Dryas cold period around 13,000 years ago (e.g., Kennett et al. 2008, 2009; Scott et al. 2010, 2017; Pinter et al. 2011; Daulton et al. 2017). Various lines of evidence, including shock-synthesized diamonds and charcoal, were cited by Kennett et al. (2008, 2009) from the islands. The authors proposed that the effects of an impact could also account for the extinction of the islands' pygmy mammoths and a hiatus in the archeological record lasting for several hundred years. Scott et al. (2010, 2017) and Pinter et al. (2011) regarded the evidence as more mundane or even misidentified. Regardless of whether there was an extraterrestrial event 13,000 years ago, the end of the Pleistocene included a number of important events on the northern islands, such as shrinking land area, increased aggradation, rapid shifts in vegetation, mammoth extinction, and the arrival of humans.

Humans were present on the Channel Islands by the latest Pleistocene, as shown by the dates associated with Arlington Man. Hardiman et al. (2016) estimated that humans first arrived on Santa Rosa Island between 13,590 and 12,720 cal yr BP (years before present; cal yr BP are radiocarbon dates that have been calibrated to calendar dates. In this document, radiocarbon dates that were not calibrated by the original authors have been calibrated using Calib 7.1 [http://calib.org/calib/] where appropriate). Santa Rosa Island's archeological record goes back to around 13,000 cal yr BP, and San Miguel Island's archeological record begins at least 11,500 cal yr BP (Erlandson et al. 2007). Pollen indicates a coastal conifer forest was present on Santa Rosa Island when people first arrived on the islands. This forest was replaced at approximately 11,800 cal yr BP by grassland and scrub as the climate warmed. The dry early Holocene was followed by increased moisture around 6,900 cal yr BP (Anderson et al. 2010). Aridity increased again for the period 5,200–3,250 radiocarbon yr BP (Cole and Liu 1994).

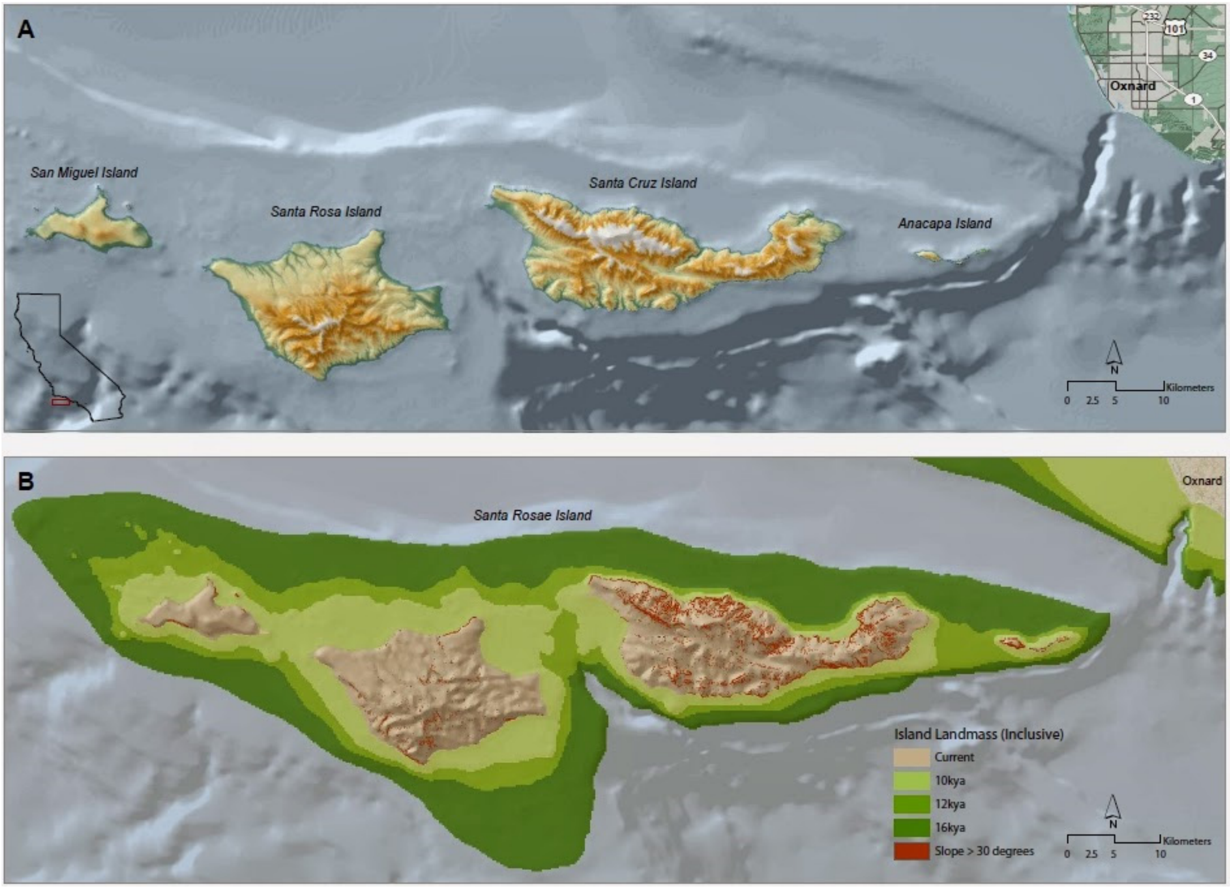

Figure 4. A comparison of the modern northern Channel Islands (A) and Santarosae (B). Different color bands on B show shorelines at different times in the recent past. Figure 1 in Collins (2009), used here courtesy of the Santa Barbara Museum of Natural History.

Each island in CHIS has distinct stratigraphy, which is detailed in the following sections dedicated to each island. A number of these formations were named from rock exposures on the islands, including the following:

- From San Miguel Island, the Mirounga and Point Bennett formations (two names for the Upper Cretaceous rocks), San Miguel Volcanics, and South Point Formation;
- From Santa Rosa Island, the Beechers Bay Formation, Santa Rosa Island Formation (another name for the island's Quaternary sediments), and Santa Rosa Island Volcanics;
- And on Santa Cruz Island, the Alamos Tonalite, Blanca Formation, Cañada Formation, Jolla Vieja Formation, Middle Anchorage Alluvium, Potato Harbor Formation, Pozo Formation, Santa Cruz Island Formation (another name for the island's young Quaternary sediments), Santa Cruz Island Schist, Santa Cruz Island Volcanics, and Willows Plutonic Complex.

These units are often of limited extent. The great majority of the formations exposed within CHIS are fossiliferous, with the chief exceptions being the igneous and metamorphic units (although fossils have been found in sedimentary beds interfingered with the Miocene volcanics of the islands). It should be noted that the stratigraphic nomenclature of the islands is unsettled. Although significant differences were discussed in the text where relevant, settling the various arguments is beyond the scope of this document.

Many units have been given relative dates based on microfossil content, particularly by the various authors in Weaver et al. (1969a). (For reference, “microfossils” are fossils which are too small to readily see with the naked eye, and therefore require magnification to properly observe. Examples include fossil pollen and “shells” or tests produced by some aquatic single-celled organisms. Fossils which can be seen with the naked eye are generally called “macrofossils”. In paleobotany a third term, “megafossil”, is used for particularly large specimens such as logs; however, in other fields of paleontology this distinction is not made as firmly, and authors may use “macrofossil” and “megafossil” interchangeably. To avoid any confusion with the paleobotanical usage, “macrofossil” will be used here where authors used “megafossil” outside of a paleobotanical context. In a further complication, vertebrate paleontologists may apply the term “microvert” or “microvertebrate” to small but not microscopic bones.) The authors in Weaver et al. (1969a) attempted to place assemblages of foraminifera (“amoebas with shells”) in the California benthic foraminiferal stages, a regional biostratigraphic scheme for the Cenozoic. In some cases, the foraminiferal stages are the only dates that have been made for these units at a finer scale than epoch. To improve understanding of the time frames involved, approximate dates have been provided for these stages in the text based on Figure 4.2 in McDougall (2007) (Figure 5), but note that precise placement of stage boundaries has been difficult, as discussed in that publication: the stages as traditionally defined are time-transgressive and overlapping. Figure 6 shows the stratigraphy of the three largest islands compared to these stages.

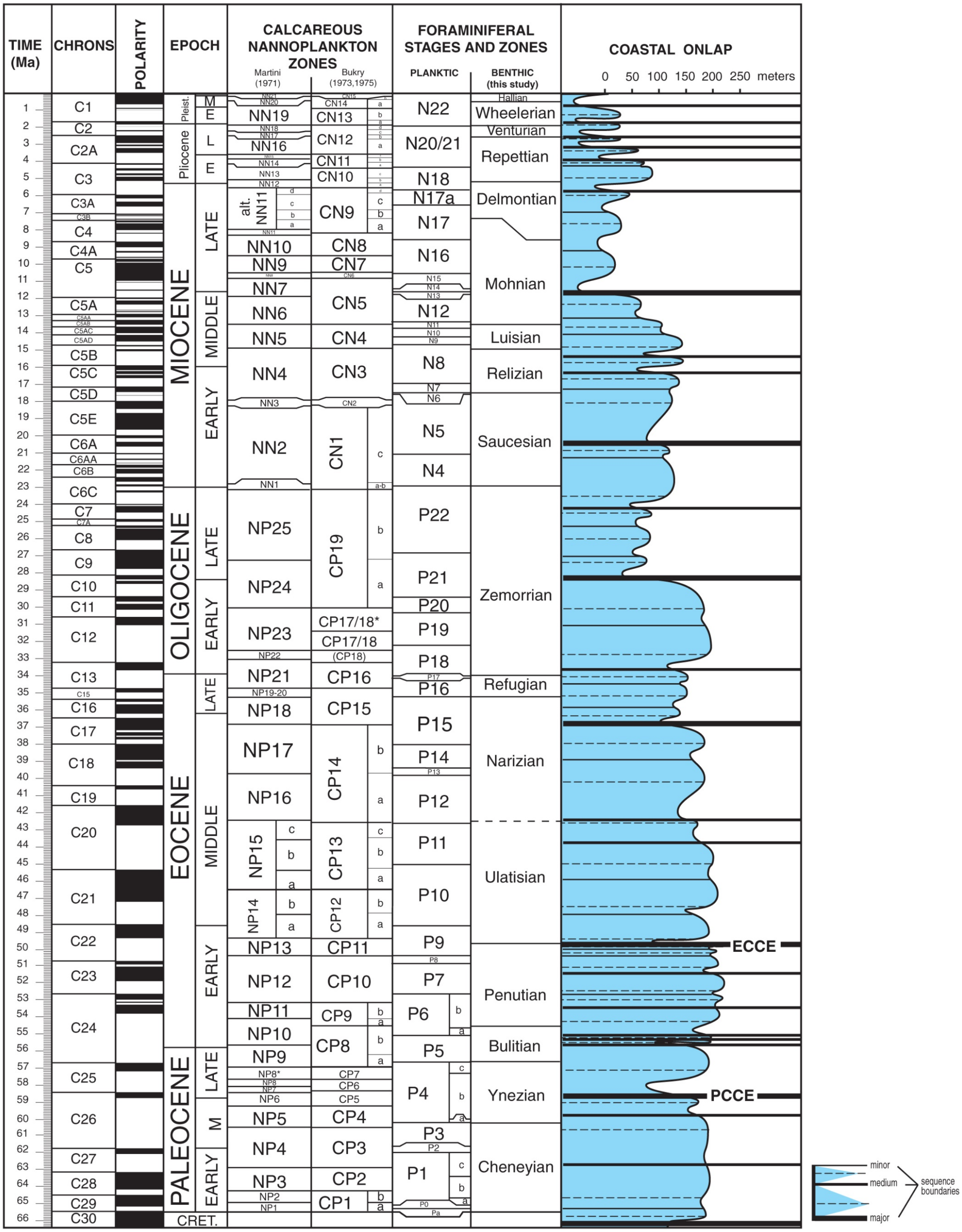

Figure 5. Foraminiferal zones and nannoplankton zones used in California compared to international geologic chronology (Figure 4.2 in McDougall 2007). Dating of stage boundaries is slightly outdated, generally within a million years of present dates for boundaries (compare Appendix E).

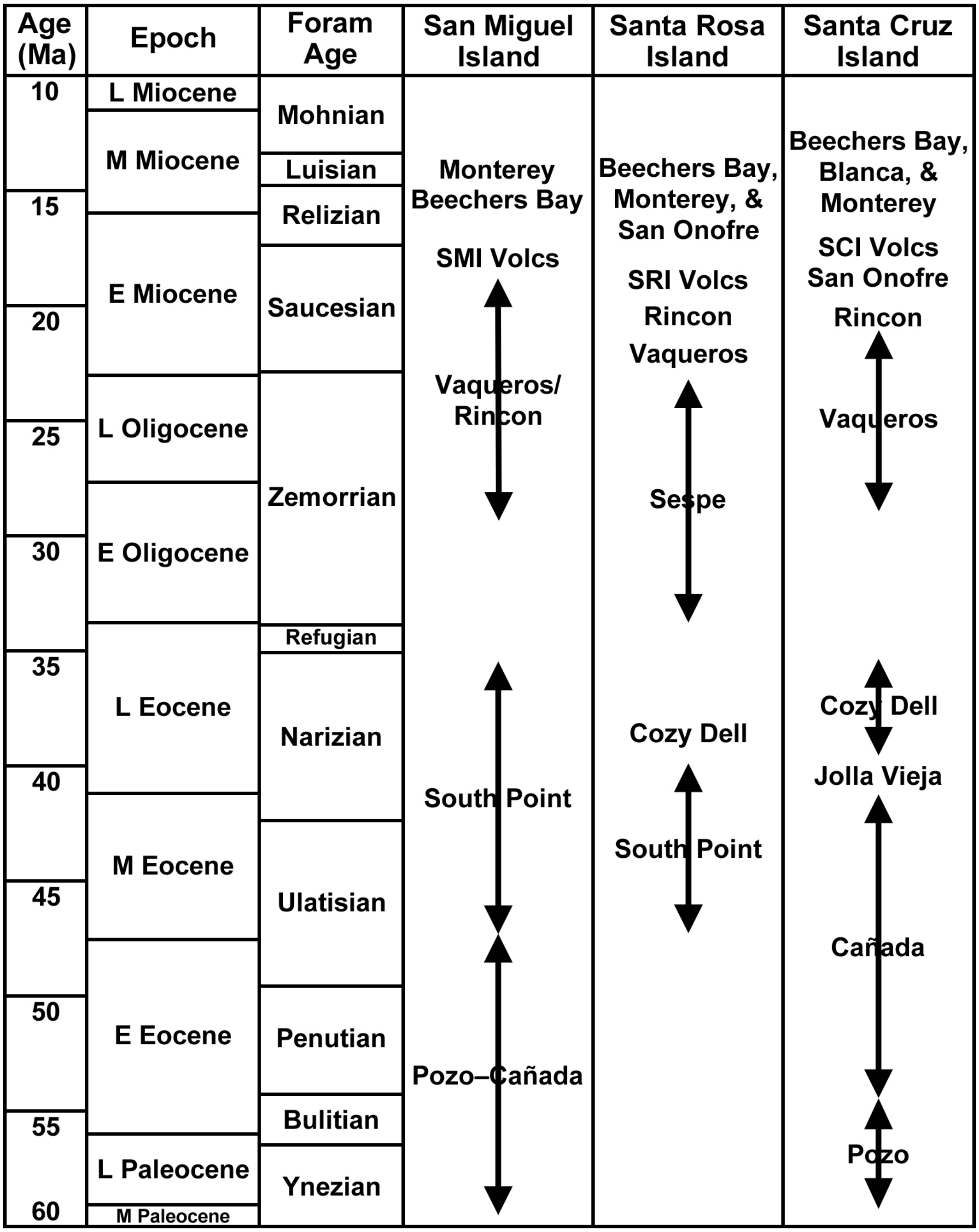

Figure 6. A comparison of the stratigraphy of the three largest islands (NPS/JUSTIN TWEET).

San Miguel Island Geology

Geologic units exposed on San Miguel Island include the following, in ascending order (lowest to highest in position, oldest to youngest in age): Jalama Formation (Upper Cretaceous); undifferentiated Pozo–Cañada Formation (Middle Paleocene–Middle Eocene); South Point Formation (Middle–Upper Eocene); Vaqueros Formation and/or Rincon Formation (Upper Oligocene?–Lower Miocene); San Miguel Volcanics (Lower Miocene); Beechers Bay Formation (Lower–Middle Miocene); Monterey Formation (Middle Miocene); and Quaternary sediments (Pleistocene–Holocene) (Weaver and Doerner 1969c; Dibblee and Ehrenspeck 2001) (Figure 7, Table 1). Alternative names have been used for some of these formations, and are discussed below.

The geologic maps included in this inventory are based on existing maps digitized by the NPS Geologic Resources Inventory (GRI). The source maps for the bedrock on San Miguel, Santa Cruz, and Santa Rosa islands are the geologic maps included in the 1969 "Geology of the northern Channel Islands" volume, while surficial data on all five islands has been compiled from recent mapping by the U.S. Geological Survey. A page in the IRMA data store (https://irma.nps.gov/Datastore/Reference/Profile/2194552) maintains links to all of the CHIS GRI mapping products. For more information about these maps, see the "Geologic Maps" section under "Paleontological Resource Management and Protection" below.

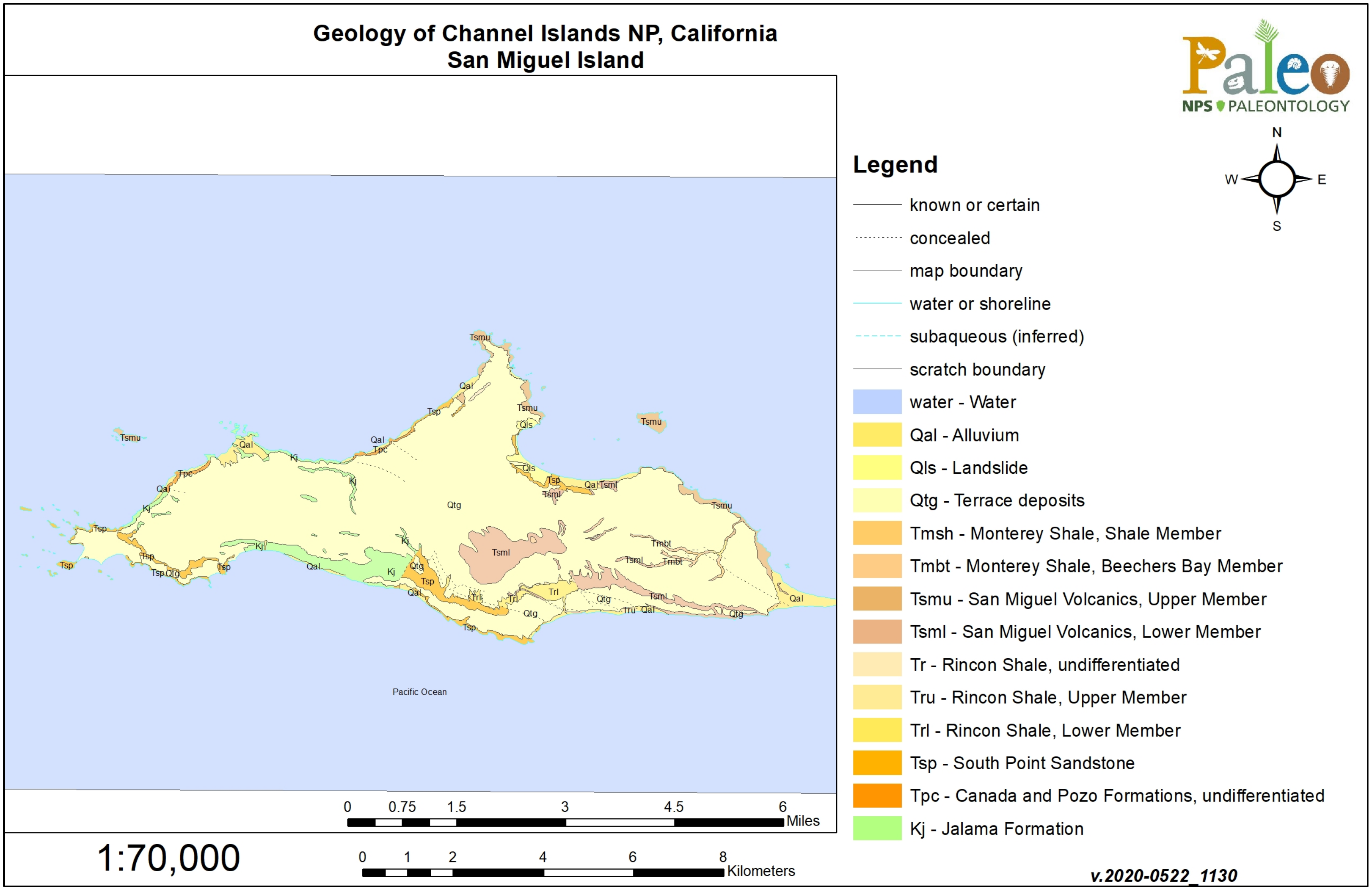

Figure 7. Geological map of San Miguel Island derived from Weaver and Doerner (1969c), digitized by the NPS GRI. All geologic units can be considered fossiliferous except Tsmu (upper volcanics). Digital map data is available at https://irma.nps.gov/DataStore/Reference/Profile/2244144.

Table 1. Summary of San Miguel Island stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. Details and references can be found in the text and in Tweet et al. (2012).

Formation	Age	Fossils Found on San Miguel Island	Depositional Environment
Quaternary rocks and sediments	Pleistocene–Holocene	Conifers, flowering plants, undetermined plant remains (including rhizoconcretions), corals, chitons, bivalves, gastropods, undetermined mollusks, barnacles, crabs, echinoids, undetermined invertebrates, sharks, ray-finned fish, frogs, lizards, snakes, diverse birds, shrews, rodents, bats, canids, skunks, pinnipeds, mammoths, deer (likely mainland), cetaceans, bird eggshells and probable nesting burrows, foraminifera, red algae, and fungal fragments	Shallow marine to terrestrial settings
Monterey Formation (shale member)	Middle Miocene	Bivalves, foraminifera, and diatoms	Marine
Beechers Bay Formation	Early–Middle Miocene	Brachiopods and bivalves	Submarine fan
San Miguel Volcanics	Early Miocene	Foraminifera	Subaqueous (likely submarine) volcanic flows
Vaqueros/Rincon Formation	Late Oligocene?–Early Miocene	Bryozoans, bivalves, gastropods, barnacles, echinoids, and foraminifera	Open marine, continental shelf
South Point Formation	Middle–Late Eocene	Bivalves, gastropods, undetermined mollusks, crabs, undetermined invertebrates, invertebrate ichnofossils, coccoliths, and foraminifera	Submarine fan, bathyal depths
Undifferentiated Pozo–Cañada Formation	Middle Paleocene–Middle Eocene	Bivalves, invertebrate ichnofossils, coccoliths, and foraminifera	Marine basin and submarine fan settings
Jalama Formation	Late Cretaceous	Bivalves, invertebrate ichnofossils, coccoliths, and foraminifera	Submarine fan, continental shelf to continental slope

Geologic Formations

Jalama Formation (Upper Cretaceous) (Kj)

Description: The Cretaceous strata of San Miguel Island are thick, including 1,928 m (6,325 ft) (Weaver 1969b) or more (Dibblee and Ehrenspeck 2001) of gray, buff, and red sedimentary rocks, primarily sandstone, siltstone, and shale (Weaver 1969b). These rocks are mapped around the coast of the western half of the island (Figure 7). The upper beds are mostly massive sandstone beds and thin interbeds of mudstone and shale. Below this, the middle and lower intervals are noted for "cyclic sequences of thinly laminated mudstone/shale beds which terminate upward into thin to thick sandstones" with some interbedded conglomerate and limy lenses (Miller 1983). The Jalama Formation represent submarine fan deposits, from the middle fan (Dibblee and Ehrenspeck 2001), with the repetitive sequences representing gravity flows such as turbidites (Miller 1983). Fossils indicate an outer continental shelf or upper continental slope location (Weaver 1969b). The upper contact with the undivided Pozo–Cañada Formation is reported as conformable (Weaver 1969b; Dibblee and Ehrenspeck 2001). However, other mapping has shown that some rocks mapped as lower Cenozoic are actually Upper Cretaceous (Bartling and Abbott 1983; Miller 1983, 1985), and microfossil biostratigraphy suggests that the Jalama Formation of San Miguel Island does not extend to the end of the Cretaceous (Miller 1983). Instead, the microfossils indicate deposition from the early Turonian stage (approximately 93 Ma) into but not through the Maastrichtian stage (approximately 70 Ma), with a hiatus during the Santonian stage (approximately 85.8–83.5 Ma) (Miller 1983, 1985). Kies (1982) found that there was also a distinct sandstone of latest Maastrichtian age, and an unconformable contact with the overlying Cenozoic rocks.

The Upper Cretaceous rocks on San Miguel Island were first lumped with overlying strata as undivided Eocene strata (Bremner 1933). These Cretaceous rocks have been known under several names, including the Jalama Formation, the Mirounga Formation, and the Point Bennett Formation. The Jalama Formation name, previously used in the Santa Ynez Mountains on the mainland, was introduced to the island by Weaver (1969b). It is used here for consistency with the GRI map, which in turn uses the 1969 map. Other authors have disagreed with the application of the mainland name to the island, and have proposed new names based on rocks found on the island itself: the Mirounga Formation (Kies 1982; Bartling and Abbott 1983; Miller 1985) and the Point Bennett Formation (Dibblee and Ehrenspeck 2001). Based on nomenclatural priority, the Mirounga Formation would take precedence over the Point Bennett Formation. It appears that the Cretaceous rocks of the island correlate to several formations including the Jalama Formation (Miller 1983, 1985).

<u>Fossils found on San Miguel Island</u>: The Upper Cretaceous rocks of San Miguel Island are "essentially devoid" of macrofossils, but microfossils are locally abundant (Weaver 1969b). Douglas (1969) briefly reported on foraminifera (amoeba-like protists that form "shells") from these rocks, and named the new planktonic species *Globotruncana marianosi*. Weaver (1969b) tabulated foraminifera from five localities on the island. Bartling and Abbott (1983) reported on samples of coccoliths (algal plates, also known as calcareous nannofossils) and foraminifera, and also mentioned the presence of general bioturbation of the sediment by animals dwelling in it. Miller (1983, 1985) described coccoliths from 69 localities on the northwest coast. Foraminifera are most abundant in the lower part of the formation (Weaver 1969b). The only macrofossil reported is the distinctive giant Mesozoic bivalve *Inoceramus* (Bartling and Abbott 1983).

<u>Fossils found elsewhere</u>: Although the Jalama Formation is known from a wider area than San Miguel Island, because the use of the name on the island is controversial, it seems prudent to not potentially introduce confusion by comparisons with rocks that may not be comparable or only partially comparable.

Undifferentiated Pozo–Cañada Formation (Middle Paleocene–Middle Eocene) (Tpc)

<u>Description</u>: The individual Pozo and Cañada formations are found on Santa Cruz Island (see below), but the undifferentiated Pozo–Cañada Formation is found only on the northwestern coast of San Miguel Island (Weaver and Doerner 1969a). It was initially described as a 685 m (2,250 ft)-thick

sequence dominated by dark gray and rusty siltstone, with some sandstone and conglomerate (Weaver and Doerner 1969a); however, as noted above, later mapping has shown that some rocks mapped as this unit are actually Upper Cretaceous (Bartling and Abbott 1983; Miller 1983, 1985). Kies (1982) suggested replacing the name with the Mount Soledad Formation, and Dibblee and Ehrenspeck (2001) replaced it with a 700 m (2,300 ft)-thick Paleocene-age Cañada Formation, with a conformable relationship to the island's Cretaceous rocks. The unit includes some "Poway-style" conglomerates (Weaver and Doerner 1969a; Kamerling and Luyendyk 1985). The upper contact with the South Point Formation is conformable (Weaver and Doerner 1969a).

The undifferentiated Pozo–Cañada Formation is a marine unit including basinal and submarine fan deposition (Kies and Abbott 1982); conglomerates record the arrival of one fan amidst otherwise sediment-starved basin deposits (Abbott et al. 1983). Weaver and Doerner (1969a) found that the microfossils of the unit pertain to the Ynezian to Ulatisian California benthic foraminiferal stages, giving a Middle Paleocene–Middle Eocene age (approximately 60.3–42.5 Ma if the entire range is represented, using foraminiferal stage dates estimated from McDougall 2007, but note that precise placement of stage boundaries has been difficult, as discussed in that publication). Kies (1982) and Kies and Abbott (1982) contracted the range to primarily the middle Early Eocene.

<u>Fossils found on San Miguel Island</u>: Burrows and bioturbation (Kies 1982), coccoliths, foraminifera (Weaver and Doerner 1969a; Kies 1982), and one report of the bivalve *Solen* sp. of uncertain stratigraphic position (Bremner 1933). Weaver and Doerner (1969a) described seven collections of coccoliths and foraminifera, which they used for biostratigraphic and paleoecological investigations. Additional collections were studied by Kies (1982).

<u>Fossils found elsewhere</u>: This unit is limited to San Miguel Island.

South Point Formation (Middle–Upper Eocene) (Tsp)

<u>Description</u>: The South Point Formation is composed mostly of buff or gray, medium- to fine-grained, thin-bedded to massive sandstone, with some shaly or silty intervals and beds. It can be quite thick, with 890 m (2,920 ft) exposed at Crook Point (Weaver and Doerner 1969a), but the maximum thickness is unknown due to faulting (Dibblee and Ehrenspeck 1998). This unit is mapped around the coast of the western two-thirds of San Miguel Island (Figure 7), and is also mapped on Santa Rosa Island (see below). The upper contact with Miocene rocks is disconformable (Weaver and Doerner 1969a; Dibblee and Ehrenspeck 2001).

The South Point Formation is interpreted as sediment transported from the west by gravity-driven flows onto a submarine fan located at bathyal depths (Erickson 1975). It has foraminifera from the Ulatisian and Narizian stages (approximately 49.6–35.3 Ma), making it age-equivalent to the Jolla Vieja Formation and part of the underlying Cañada Formation on Santa Cruz Island. The oldest part of the formation is exposed on San Miguel Island (Weaver and Doerner 1969a).

<u>Fossils found on San Miguel Island</u>: Most of the fossils reported from the South Point Formation of San Miguel Island are coccoliths or foraminifera (Weaver and Doerner 1969a; Kies 1982). Weaver and Doerner (1969a) identified coccoliths from five localities and foraminifera from 25 localities.

Fragmentary remains of larger shelled invertebrates, mostly attributed to bivalves (Bremner 1933; Kies 1982) and gastropods (Kies 1982), are also known, as well as an articulated crab and general bioturbation (Kies 1982).

Fossils found elsewhere: The South Point Formation is also fossiliferous on Santa Rosa Island; its fossil assemblage is similar to that on San Miguel Island, but it has also yielded ostracodes (seed shrimp), ray teeth, and diatoms (siliceous plankton microfossils) (Weaver and Doerner 1969a). Most fossils on both islands have been found in the finer-grained rocks, not the sandstone facies (Weaver and Doerner 1969a).

Vaqueros/Rincon Formation (Upper Oligocene?–Lower Miocene) (Tr)

Description: Historically, geologists working in coastal California used a system of formations defined by fossil content instead of lithology. These formations were widely applied during the first few decades of the 20th century, until most were redefined to fit lithological units, limited to usage as biostratigraphic zones, or abandoned altogether (see Fritsche 1993 or Campbell et al. 2007 for some discussion of this phenomenon). Among these units were the Vaqueros and Temblor formations, which were applied to rocks with specific middle Cenozoic mollusk assemblages, including on San Miguel Island (Arnold 1906; Hertlein 1928; Loel and Corey 1932; Bremner 1933). However, Weaver and Doerner (1969b) assigned the "Vaqueros" and "Lower Temblor" rocks in question to the Rincon Formation, and since that time opinion has been divided on the nomenclature for the island's pre-volcanic Miocene rocks. Some consider the rocks to include a lower Vaqueros Formation interval and upper Rincon Formation interval (McLean et al. 1976a; Dibblee 1982a; Smith 1991; Dibblee and Ehrenspeck 2001), and others use the Rincon Formation only (Miller 1983; Kamerling and Luyendyk 1985; Champion et al. 1986). The Geologic Resources Inventory map of the island is based on the work of Weaver and Doerner, and so uses Rincon Formation exclusively; however, in light of the controversy, this work does not commit to a specific usage. See the Rincon Formation and Vaqueros Formation entries in the Santa Rosa Island section for more details specific to these formations.

On San Miguel Island, the rocks in question are mostly limited to an area on the south coast of the island. The stratigraphic interval is up to 385 m (1,260 m) thick and can be divided into two informal members. The lower member is composed of greenish-gray, buff, or brown soft shale, with some mollusk-rich sandstones and conglomerate beds. The upper member takes in the upper 76 m (250 ft) of the formation, and consists of light brown to dark brown shale with lenses of calcareous (lime-rich) beds that weather white. The upper contact with the overlying volcanics is conformable and interbedding (Weaver and Doerner 1969b). The basal beds of the interval, composed of medium- to fine-grained olive-tan to yellow-gray-weathering sandstone and interbedded silty shale, may actually be the Sespe Formation (see "Sespe Formation" under "Santa Rosa Island" for more information on this unit) (Weaver and Doerner 1969a).

The Vaqueros/Rincon rocks were deposited in much shallower water than the underlying South Point Formation. Shelf foraminifera are present in the upper member. The foraminifera and mollusk assemblages indicate a late Zemorrian–early Saucesian age (the Zemorrian–Saucesian boundary is approximately 23.0 Ma) (Weaver and Doerner 1969b).

Fossils found on San Miguel Island: Bryozoans (Bremner 1933), bivalves, gastropods (Hertlein 1928; Loel and Corey 1932; Bremner 1933; Weaver and Doerner 1969b), barnacles, echinoids (sea urchins) (Loel and Corey 1932; Bremner 1933), and foraminifera (Weaver and Doerner 1969b) have been reported. In the lower member, foraminifera are found in the shale beds, and mollusks in the sandstone (Weaver and Doerner 1969b). Weaver and Doerner (1969b) provided lists of foraminifera found at four localities (two in each member). Several mollusk taxa have been named from these rocks, including the bivalves *Ostrea miguelensis* (holotype California Academy of Sciences [CAS] 4121; Hertlein 1928) and *Pecten* (*Lyropecten*) *miguelensis* (holotype University of California Museum of Paleontology [UCMP] IP12943; Arnold 1906) and the gastropod *Fissurella rixfordi* (holotype CAS 4145; Hertlein 1928). The potential Sespe Formation rocks at the base of the interval contain "scattered, badly broken and worn, unidentifiable megafossils" (Weaver and Doerner 1969a).

Fossils found elsewhere: See the Rincon Formation and Vaqueros Formation entries in the Santa Rosa Island section for more details specific to these formations.

San Miguel Volcanics (Lower Miocene) (Tsm)

Description: All five of the islands of CHIS have Lower–Middle Miocene volcanic rocks, formed during a spate of igneous activity between 19 and 13 Ma, a consequence of the tectonic rotation of the Transverse Ranges (Weigand and Savage 1999). Often, these rocks are either classified with the Conejo Volcanics of the mainland (e.g., Dibblee 1982a) or assigned to formal or informal geologic formations named after the host island. The volcanic intervals also have associated sedimentary rocks, which usually have sparse marine fossils. For the purposes of this report, each island's Miocene volcanic/sedimentary interval will be considered a separate formation.

The San Miguel Volcanics are at least 460 m (1,520 ft) thick, and are composed of volcanic flows, breccia, sandstone, and siltstone. The volcanics can be divided into informal lower and upper members (Weaver and Doerner 1969b). The lower member is composed of basalt flows and volcaniclastic (volcanic rock fragments) sedimentary rocks, found in the southeastern part of the island, and the upper member is composed of dacite, found in the northern part of the island (Weaver and Doerner 1969b). When the formation was first described, it was also applied to the volcanic rocks on Santa Rosa Island (Avila and Weaver 1969; Weaver and Doerner 1969b), where the lower member was thought to be present (Weaver and Doerner 1969b); since then, the Santa Rosa Island volcanics have been separated as their own formation. The upper contact with the Beechers Bay Formation is conformable (Weaver and Doerner 1969b). The flows were erupted subaqueously, probably in a submarine setting (Weaver and Doerner 1969b). They date to between 18.5 and 17.0 Ma (Weigand and Savage 1999).

Fossils found on San Miguel Island: Weaver and Doerner (1969b) described foraminifera from a locality in the lower member.

Fossils found elsewhere: This collective unit is limited to San Miguel Island.

Beechers Bay Formation (Lower–Middle Miocene) (Tmbt)

Description: The Beechers Bay Formation of San Miguel Island is composed of white tuffaceous sandstone ("tuff" is rock composed of volcanic ash) and buff-colored volcaniclastic sandstone exposed in the eastern part of the island (Weaver and Doerner 1969b). It is marine in origin, with continental shelf fossils (Weaver and Doerner 1969b). Deposition occurred on a submarine fan (Weigand and Savage 1999). Fossils may be of Relizian age (approximately 17.5–15.0 Ma) (Weaver and Doerner 1969b). On San Miguel Island, the upper contact with the Monterey Formation is concordant, if not necessarily conformable (Weaver and Doerner 1969b). Bremner (1933) described these rocks as the "Upper Temblor".

The Beechers Bay Formation was first formally designated as a member of the Monterey Formation (Avila and Weaver 1969), but more recent usage has favored recognizing it as a formation in its own right (Chinn and Weigand 1994; Dibblee and Ehrenspeck 1998; Dibblee et al. 1998; Nuccio and Woolley 1998; Weigand and Savage 1999). It is sometimes interpreted as the finer-grained equivalent of the Blanca Formation of Santa Cruz Island (Howell and McLean 1976).

Fossils found on San Miguel Island: The Beechers Bay Formation of San Miguel Island has yielded brachiopods (lamp shells) (Weaver and Doerner 1969b) and bivalves (Bremner 1933; Weaver and Doerner 1969b).

Fossils found elsewhere: The Beechers Bay Formation on Santa Rosa Island has also produced bivalves, foraminifera (Avila and Weaver 1969), and apparently invertebrate burrows (Howell and McLean 1976). On Santa Cruz Island, bivalves, barnacles, and foraminifera have been reported (Bereskin and Edwards 1969).

Monterey Formation (shale member) (Middle Miocene) (Tmsh)

Description: The Monterey Formation was originally named from outcrops on the California mainland. Like the Vaqueros Formation, the Monterey Formation was first used to describe a characteristic fossil assemblage and was later adapted to serve as a lithostratigraphic unit. It has been used to describe an interval of Miocene rocks on the three large islands of CHIS, divisible into two members: a shale member and the coarser Beechers Bay Member, which was named from Santa Rosa Island (Avila and Weaver 1969). The use of the Monterey Formation name on the islands has been challenged (Avila and Weaver 1969; McLean et al. 1976a; Nuccio and Woolley 1998), and, as noted above, the Beechers Bay Member is often raised to a formation. Although it may be redundant to identify the shale member of the Monterey Formation as the shale member if it is considered the only member, it will be identified as such in this document when that name was used in the original source, to preserve authorial intent and avoid confusion with the Beechers Bay Formation in the event of future changes in nomenclature.

On San Miguel Island, outcrops of the shale member are limited to small areas in the east. The shale member is composed of yellow-gray and light brown soft shale, with a basal conglomerate approximately 3 m (10 ft) thick made up of reddish dacite cobbles. Foraminifera in the shale member are of Luisian age (approximately 15.0–13.6 Ma) and indicate an outer shelf setting (Weaver and Doerner 1969b).

Fossils found on San Miguel Island: The shale member of the Monterey Formation is fossiliferous on San Miguel Island, having yielded bivalves, foraminifera, and diatoms from a continental shelf setting. Foraminifera can be abundant, and the bivalve *Lyropecten crassicardo* forms local reefs in calcareous beds (Weaver and Doerner 1969b). Bremner (1933)'s *Pecten* cf. *P. peckhami*, the only bivalve he reported from this unit, may be the same taxon. Weaver and Doerner (1969b) listed taxa from two foraminifera localities.

Fossils found elsewhere: On Santa Rosa Island, the shale member has fossils of bivalves, foraminifera, and diatoms (Avila and Weaver 1969). On Santa Cruz Island, it has yielded bivalves, gastropods (Rand 1931, 1933; Weaver and Meyer 1969), fish scales and bones (Weaver and Meyer 1969), an unnamed desmostylian (Barnes and Aranda-Manteca 1997; Domning and Barnes 2007), cetacean bones (Weaver and Meyer 1969), foraminifera (Weaver and Meyer 1969), and diatoms (Rand 1931; Weaver and Meyer 1969).

Quaternary rocks and sediments (Pleistocene–Holocene)

Description: Quaternary rocks and sediments on San Miguel Island include marine terrace deposits, terrestrial alluvium, landslide deposits, eolian deposits, sediments in caves and rock shelters, and consolidated caliche beds.

Fossils found on San Miguel Island: San Miguel Island has an excellent late Pleistocene–Holocene fossil record, encompassing everything from the bones of pygmy mammoths (Stock 1935) to fragments of foraminifera and mollusks among sediment grains (Johnson 1969). The strong winds of San Miguel Island can erode and deflate loose sediment to a depth of 20 cm (8 in), concentrating Holocene bones (Rick 2002). Exploration of the island's Quaternary fossils increased beginning in the late 1970s, particularly in caves and the unconsolidated sediments on the northern end of the island (Guthrie 1998). A paleontological resource survey took place from 1984 to 1985 (Guthrie 1993).

One of the signature types of Quaternary fossils on San Miguel Island is calichified plant structures. These fossils are also found on several other Channel Islands, but they are particularly abundant on San Miguel Island, where they have formed "fossil forests" (Figure 8). The use of "fossil forest" is something of a misnomer, because most of the plant structures represented are roots, not trunks. For this reason, they are also called rhizoliths (a technical term for root casts) or rhizoconcretions. See "Fossil Plants" under "Taxonomy" for more details on these structures. Johnson (1977) used them to infer the presence of shrub vegetation during the latest Pleistocene. However, pollen indicates the presence of a pine forest for at least the northeast coast of the island near the end of the Pleistocene, transitioning into a coastal shrub assemblage near the Pleistocene–Holocene boundary (West and Erlandson 1994; Erlandson et al. 1996). R. Scott Anderson (Northern Arizona University, pers. comm., April 2020) has a small late Holocene pollen record from near the airstrip. Macroscopic plant fossils known from the late Quaternary of San Miguel Island include the trees *Cupressus* (cypress) (Johnson 1981) and *Pinus* (pines) and the shrubs *Rhus* (sumacs) and *Ribes* (currants) (Johnson 1977).

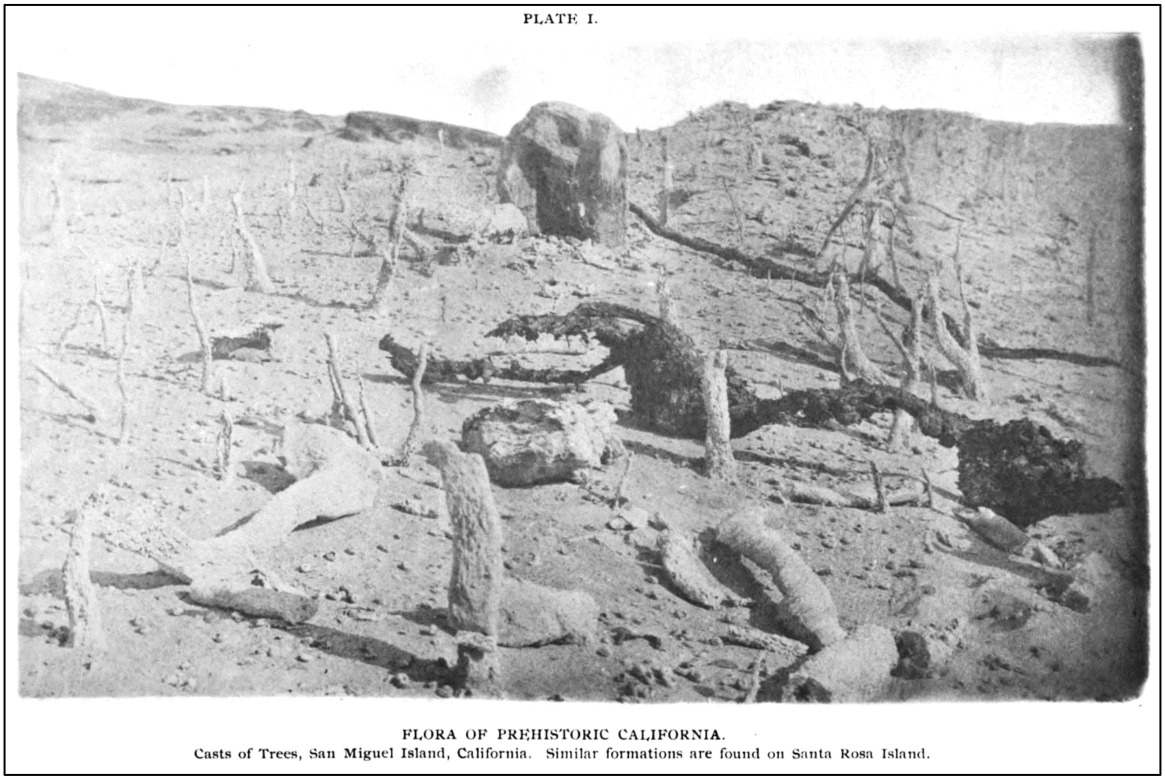

Figure 8. A "fossil forest" of calichified plant remains on San Miguel Island, in a plate first published in Yates (1902–1905:1(9):113–118) but intended for Voy (1890–1893b).

Pleistocene mollusks are extremely abundant on San Miguel Island. Terrestrial gastropod fossils have been a point of comment since the late 19th century (Bowers 1878; Voy 1890–1893b) (Figure 9). Johnson (1971) estimated that there were millions of specimens of the terrestrial gastropod *Helminthoglypta ayresiana* on the island. Cockerell (1938a) named the gastropod subspecies *Helminthoglypta ayresiana lesteri* from a specimen from the island. This subspecies has fallen out of use (Johnson 1971; Roth and Sadeghian 2006). There are also marine mollusks as old as the early Pleistocene (Johnson 1972). Bivalves and gastropods are both represented (Cockerell 1939, 1940). Holocene bivalves and gastropods have been taken from archeological sites on the island for isotopic studies of climate (Robbins et al. 2006). Muhs et al. (2014) published on the fossils from the most recent wave-cut terrace of San Miguel Island, which include corals, chitons, bivalves, gastropods, barnacles, and echinoids. The assemblage includes both warm-water and cool-water components, which is interpreted as evidence of terrace reoccupation: the terrace was cut approximately 120,000 years ago and inhabited by a warm-water fauna, then reoccupied at approximately 100,000 years ago with a cool-water fauna (Muhs et al. 2014).

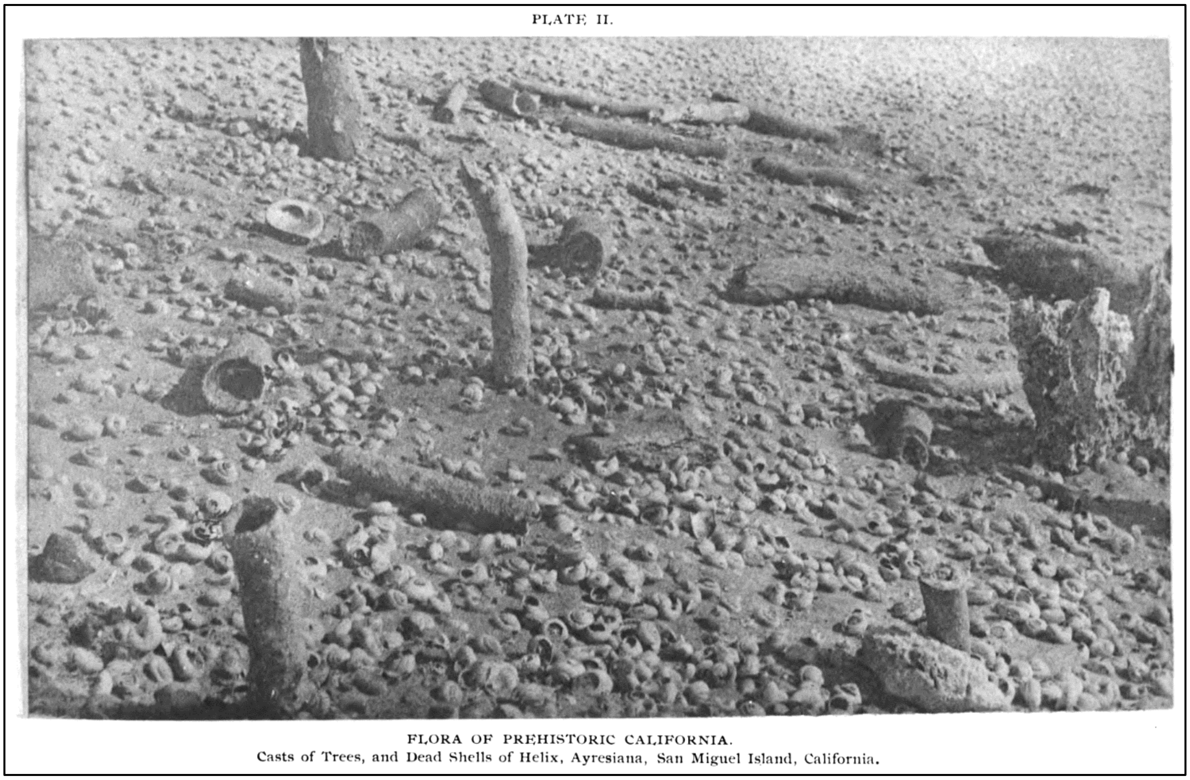

Figure 9. Abundant *Helminthoglypta ayresiana* shells among calichified plant remains on San Miguel Island, in a plate first published in Yates (1902–1905:1(9):113–118) but intended for Voy (1890–1893b).

The Quaternary vertebrate record of San Miguel Island includes sharks, bony fishes (Rick et al. 2001), the chorus frog cf. *Pseudacris* (Mead et al. 2018), the alligator lizard *Elgaria multicarinata* (Guthrie 2005), the spiny lizard *Sceloporus occidentalis becki*? (Ainis et al. 2011), the gopher snake *Pituophis melanoleucus* (Guthrie 1993), the Pacific rattlesnake *Crotalus viridis* (Guthrie 1998), diverse birds (Collins et al. 2018a), the ornate shrew *Sorex ornatus*, the extinct vole *Microtus miguelensis*, the extinct giant deer mouse *Peromyscus nesodytes* and mainland relative *P. maniculatus*, the extinct vampire bat *Desmodus stocki*, the dwarf Channel Island fox *Urocyon littoralis* (Guthrie 1998), dogs (Rick et al. 2008), the spotted skunk *Spilogale* (Walker 1980), several species of pinnipeds (Walker and Craig 1979), the pygmy mammoth *Mammuthus exilis* (Figure 10) and Columbian mammoth *M. columbi* (Pigati et al. 2017), and whales (Bremner 1933). Not all of these taxa existed at the same time. Approximately 95% of vertebrate specimens are from birds, dominated by alcids (puffins and auks) and the extinct flightless sea duck *Chendytes lawi* (Guthrie 1992). Birds and terrestrial animals seem to be divisible into two assemblages: a coastal assemblage dominated by alcids, and an inland assemblage dominated by *Chendytes*. Gastropods and *Peromyscus nesodytes* are found in both assemblages (Guthrie 1993).

Figure 10. A pygmy mammoth jaw from San Miguel Island in the collections of the Natural History Museum of Los Angeles County (LACM) (NPS/JUSTIN TWEET).

The island's record of fish and sea mammals is principally associated with human activities. Fishes are represented by sharks, clupeids, sculpins, surfperch, greenling, wrasses, flatfish, scorpionfish, and pricklebacks, with specimens collected from early Holocene cave deposits (Rick et al. 2001). Pinniped bones were collected from an archeological site dating to at least 1,100 radiocarbon yr BP, and included bones of California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina*), northern elephant seals (*Mirounga angustirostris*), Guadalupe fur seals (*Arctocephalus townsendi*), northern fur seals (*Callorhinus ursinus*), and sea otters (*Enhydra lutris*) (Walker and Craig 1979). Sea otter bones have been found in other middens as well (Mitchell 1966).

The Quaternary avifauna of San Miguel Island is represented by dozens of species and thousands of bones. The most recent summary reported at least 144 species in 15 orders: 14 species of anseriforms (ducks and geese), three gaviiforms (loons), five podicipediforms (grebes), 12 procellariiforms (petrels), at least four suliforms (gannets and cormorants), three pelecaniforms (pelicans, herons, etc.), at least 36 charadriiforms (gulls waters, etc.), two gruiforms (crane-like birds), one cathartiform (New World vulture), four accipitriforms (eagles, hawks, etc.), three falconiforms (falcons), two columbiforms (doves and pigeons), four strigiforms (owls), three piciforms (woodpeckers), and at least 48 passeriforms (perching birds) (Collins et al. 2018a). More than 22,000 bones as well as eggshells have been recovered from 23 sites, representing seabird nesting colonies, barn owl roosts, and bald eagle nest sites (Collins et al. 2018a). Four species account for more than 16,000 bones. In order of abundance, they are the extinct puffin *Fratercula dowi*, Cassin's auklet (*Ptychoramphus aleuticus*), ancient murrelet (*Synthliboramphus antiquus*), and *Chendytes lawi* (Guthrie 2005). Extinct birds are represented by *Chendytes lawi*, *Fratercula dowi*, the gannet *Morus reyanus*, and the owl *Asio priscus* (Collins et al. 2018a). The most abundant of these, *Fratercula dowi*, is represented on the island by eggs and more than 8,000 bones (Collins et al. 2018a). It was common on the island between 40,000 and 25,000 radiocarbon yr BP, and was present as recently as 12,000 radiocarbon yr BP. Several paratypes (specimens of a type series that are not the holotype, or name-bearing specimen) of the species have been designated from San Miguel Island specimens held at the Santa Barbara Museum of Natural History (SBMNH) (Guthrie et al. 1999).

The terrestrial mammal assemblage of the late Pleistocene and Holocene of San Miguel Island is small, consisting of a handful of rodents, insectivores, and small carnivorans, a bat, and mammoths. One of the constituents, the vole *Microtus miguelensis*, is named from a San Miguel Island specimen (Guthrie 1998). The pygmy mammoth (*M. exilis*, exiled mammoth) is the most famous fossil organism of CHIS (see "Fossil Vertebrates" in the "Taxonomy" section for more details). The first report of the pygmy mammoth on San Miguel Island is Gilbert (1910), which included a photo of a tooth of "*Eliphas primogenus*" loaned by Professor W. A. Fisk of Occidental College (Figure 11). Other reports include Hay (1927), Stock (1935), Hooijer (1976), Roth (1996a), Agenbroad (1998, 1999b, 2005), Gray and Harz (1998), Agenbroad et al. (2005), Rick et al. (2012b), Muhs et al. (2015), Semprebon et al. (2016), and Pigati et al. (2017). Madden (1977) and Pigati et al. (2017) reported the presence of its probable ancestor, the Columbian mammoth (*M. columbi*), on the island as well. Dogs were introduced to the island via humans by the middle Holocene at least (Rick et al. 2008). Foxes (Rick et al. 2009) and skunks (Wenner and Johnson 1980) were likely introduced by humans during the Holocene as well. Deer bones, found at an 8,000-year old archeological, probably represent imported material (Vellanoweth et al. 2003).

The Pleistocene and early Holocene inhabitants of San Miguel Island went extinct over a period of several thousand years. The snake and bat species probably went extinct before the arrival of humans (Guthrie 1998). The pygmy mammoth went extinct around 11,030 radiocarbon years ago. *Microtus miguelensis* followed at about 11,000 years ago (Knowlton et al. 2007). *Peromyscus nesodytes* went extinct on the island perhaps less than a thousand years ago (Rick et al. 2012b), possibly replaced by the smaller *P. maniculatus*, which was probably accidentally introduced by humans (Guthrie 1998). As noted, *Chendytes lawi* persisted until about 2,500 years ago (Grayson 2008; Jones et al. 2008). Shrews went extinct on the island between 1000 C.E. and the 19th century, and spotted skunks may have persisted until the late 19th century (Knowlton et al. 2007); Voy (1890–1893b) reported the capture of a skunk on the island probably during the post-Spanish period. Dog and skunk specimens may represent isolated individuals, instead of island populations (Walker 1980).

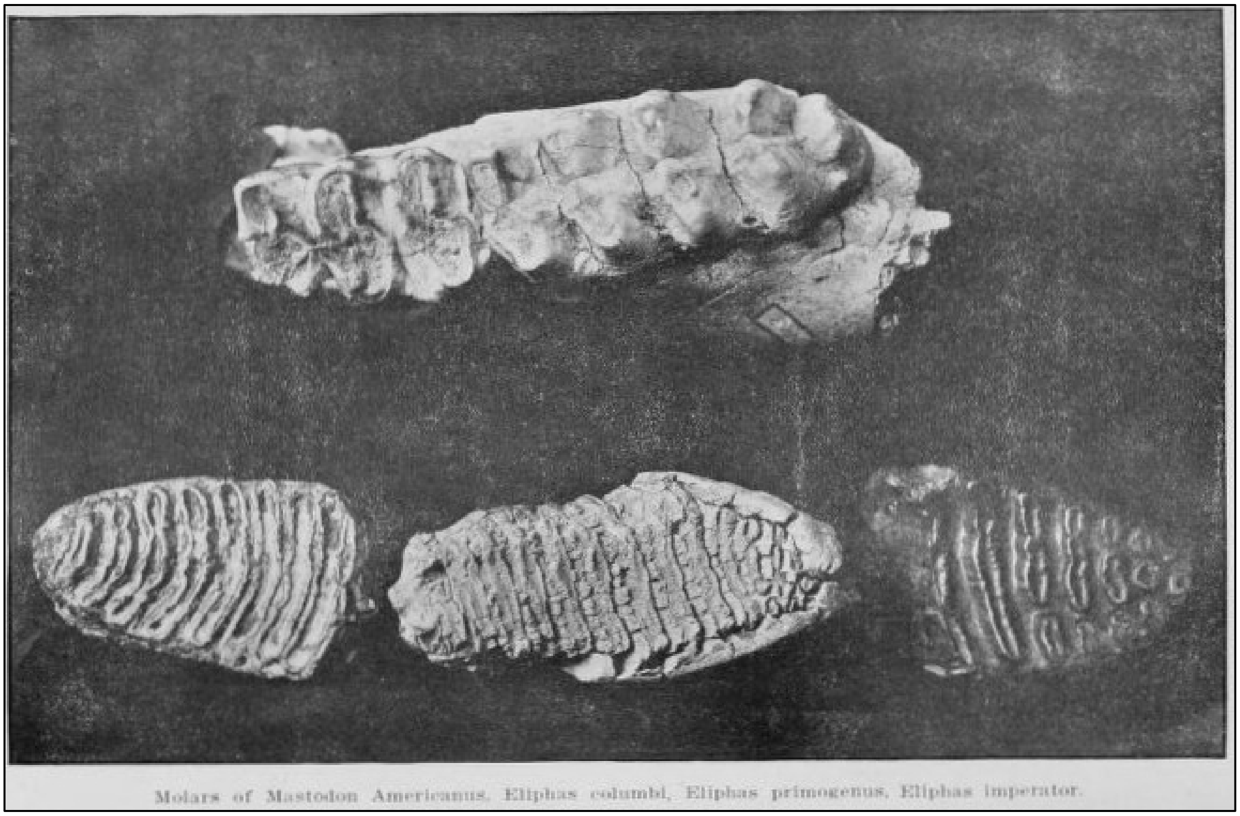

Figure 11. The lower center fossil ("*Eliphas primogenus*") is the earliest known photograph of a mammoth specimen from San Miguel Island (Gilbert 1910).

Fossils found elsewhere: As detailed in the following sections, Santa Rosa Island and Santa Cruz Island have similar Quaternary fossil records to San Miguel Island, which is unsurprising because they were also part of Santarosae during the late Pleistocene. Anacapa Island, the easternmost remnant of Santarosae, is less similar, due to the smaller remaining terrestrial acreage. Santa Barbara Island is distinct because it was never part of Santarosae.

Santa Rosa Island Geology

Like Santa Cruz Island, Santa Rosa Island is divided by a major east-west fault (Avila and Weaver 1969; Weigand and Savage 1999). The division in geology is not as stark as on Santa Cruz Island, although older rocks are only exposed in the south (Weigand and Savage 1999). There has been some recent movement on the fault (Schumann et al. 2014; Muhs et al. 2015).

Due to differences in mapping, placement of contacts, and choice of nomenclatural scheme, navigating the literature on the Miocene rocks of Santa Rosa Island requires careful attention to a given publication's definitions and frequent reference to other publications. The framework published in the 1969 monograph, which was used for the GRI maps in this publication, is different from that used in 1976, which in turn is notably different from that published in Dibblee and Ehrenspeck (1998). The unprepared reader going from the 1969 monograph to Dibblee and Ehrenspeck (1998) may well be mystified as to how the Rincon Formation can have a conformable contact with the Monterey Formation, until discovering that the latter authors have transferred much of the upper Rincon Formation to the Monterey Formation.

Units exposed on Santa Rosa Island include the following, in ascending order (lowest to highest, oldest to youngest): South Point Formation (Middle Eocene); Cozy Dell Shale (Middle–Upper Eocene); Sespe Formation (Oligocene); Vaqueros Formation and Rincon Formation (Lower Miocene); Santa Rosa Island Volcanics (Middle Miocene); Monterey Formation, San Onofre Breccia, and Beechers Bay Formation (Lower–Middle Miocene); and Quaternary rocks and sediments (Pleistocene–Holocene) (Sonneman et al. 1969; Dibblee et al. 1998) (Figure 12, Table 2). Most but not all of these units are fossiliferous. Alternative names have been used for some of these formations, and are discussed below.

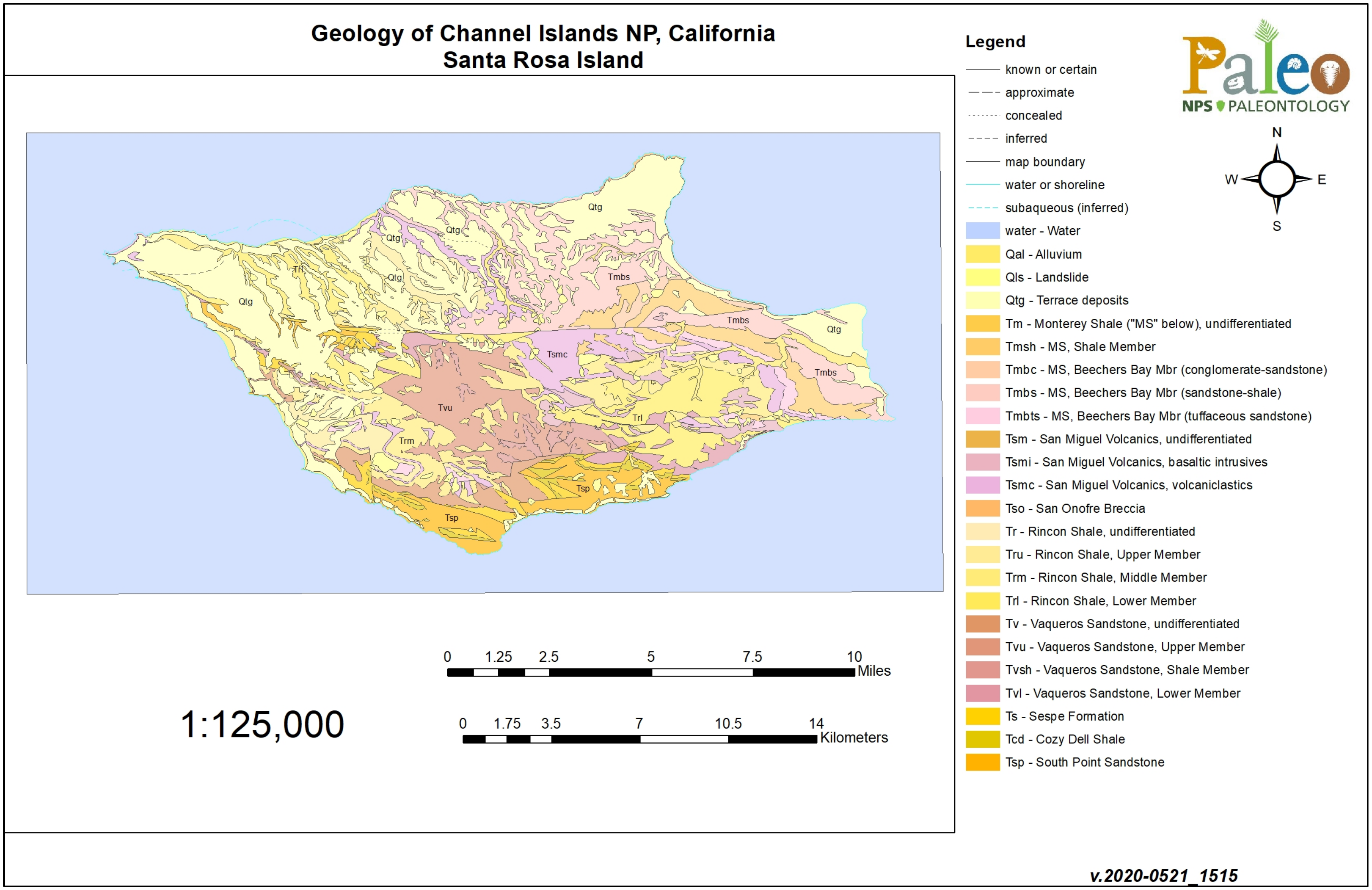

Figure 12. Geological map of Santa Rosa Island derived from Sonneman et al. (1969), digitized by the NPS GRI. Digital map data is available at https://irma.nps.gov/DataStore/Reference/Profile/2244145.

Table 2. Summary of Santa Rosa Island stratigraphy, fossils, and depositional settings in descending order of age. Details and references can be found in the text and in Tweet et al. (2012).

Formation	**Age**	**Fossils Found on Santa Rosa Island**	**Depositional Environment**
Quaternary rocks and sediments	Pleistocene–Holocene	Mosses, spikemosses, ferns, conifers, flowering plants, undiagnostic plant remains, sponges, corals, chitons, bivalves, gastropods, undetermined mollusks, barnacles, ostracodes, echinoids, reworked Miocene invertebrates, ray-finned fish, frogs, salamanders, undetermined amphibians, lizards, snakes, undetermined reptiles, diverse birds, shrews, rodents, oldest verified human skeletal remains in North America, canids, pinnipeds, mammoths, cetaceans, undetermined vertebrates, invertebrate burrows, arthropod coprolites, clam borings, barn owl pellets, radiolarians, diatoms, chrysophytes, and fungal remains	Shallow marine to terrestrial settings
Beechers Bay Formation	Early–Middle Miocene	Bivalves, invertebrate burrows, and foraminifera	Submarine fan near volcanic source
San Onofre Breccia	Early–Middle Miocene	None to date; marine invertebrates are most likely	Shallow marine, associated with volcanics
Monterey Formation (shale member)	Early–Middle Miocene	Bivalves, foraminifera, and diatoms	Outer shelf to upper slope
Santa Rosa Island Volcanics	Early Miocene	Bivalves and foraminifera	Volcanic flows and igneous intrusions
Rincon Formation	Early Miocene	Carbonaceous plant fragments, corals, bivalves, gastropods, echinoids, shell debris, fish fragments, undetermined vertebrates, foraminifera, reworked Eocene coccoliths, and diatoms; this or the Vaqueros Formation contains the sirenian locality, which has yielded bivalves, gastropods, barnacles, crab claws, shark and ray teeth, sirenians, a possible cetacean bone, and invertebrate burrows	Continental shelf
Vaqueros Formation	Early Miocene	Corals, bivalves, gastropods, serpulid worm tubes, barnacles, echinoids, and reworked Eocene coccoliths	Shallow marine inner shelf, becoming deeper over time
Sespe Formation	Oligocene	Undetermined macroscopic invertebrate fossils, possibly bivalves and burrows	Fluvial and alluvial to shallow marine?
Cozy Dell Shale	Middle–Late Eocene	Bivalves, foraminifera, and diatoms	Marine, beginning as continental slope, deepening as basin subsided
South Point Formation	Middle Eocene	Ostracodes, fish fragments, foraminifera, and diatoms	Gravity-driven flow deposition on bathyal submarine fan
Possible Cretaceous rocks	Cretaceous?	None to date; foraminifera and marine invertebrates are most likely	Marine

Geologic Formations

Possible Cretaceous rocks (Cretaceous)

Description: Cretaceous rocks have sometimes been reported from Santa Rosa Island, but have never been confirmed. One report, in Kew (1927), is demonstrably mistaken. Kew (1927) reported the presence of possible Cretaceous rocks on Santa Rosa Island, which he tentatively correlated with the Chico Formation. The section in question had coarse- to medium-grained sandstones in the lower part, and gray or maroon gypsum-rich shale with calcareous sandy beds in the upper part (Kew 1927). Kew mapped these rocks across much of southern Santa Rosa Island; comparison to modern geologic maps shows that his "Chico Formation" is a combination of outcrops pertaining to the South Point, Cozy Dell, and Sespe formations. Kew (1927) reported that the rocks were not fossiliferous, and indeed most of the fossils reported from the South Point and Cozy Dell formations are microfossils which Kew would not have found unless he specifically processed rocks for microfossils. Weaver (1969b) noted that Cretaceous rocks had been reported in a fault wedge in south central Santa Rosa Island, but that the report was unconfirmed. Weaver attributed the report to an AAPG (American Association of Petroleum Geoscientists) correlation chart from 1952, but without further bibliographic information this reference remains unseen. It is certainly not impossible that some Cretaceous rocks are present in a fault wedge on the island, given that San Miguel Island has Cretaceous rocks at the surface and Santa Cruz Island has them in the subsurface. Dibblee and Ehrenspeck (1998) noted the presence of unnamed pre-South Point Formation rocks in the subsurface of the island, which they suggested could be as old as the Late Cretaceous.

Fossils found on Santa Rosa Island: None to date; if there are any and they are correlative to the Cretaceous rocks found elsewhere in CHIS, microfossils and marine mollusks are most likely.

Fossils found elsewhere: Not yet applicable.

South Point Formation (Middle Eocene) (Tsp)

Description: The South Point Formation of Santa Rosa Island is a thick sandstone-dominated Eocene unit, deposited on a deep-water submarine fan (Dibblee and Ehrenspeck 1998). This formation was named for South Point on Santa Rosa Island, where the upper part is exposed (Weaver and Doerner 1969a). It is mapped in two main areas on Santa Rosa Island: on the south coast and south of the Santa Rosa Island Fault in the west part of the island (Figure 12) (Sonneman et al. 1969). It is mostly composed of hard, light gray, fine- to medium-grained arkosic sandstone in meter-scale beds, separated by shale or softer sandstone partings. Only part of the formation is visible on the island; well logs indicate it can be 1,070–1,080 m (3,510–3,540 ft) thick before it passes into unnamed older beds of shale, conglomerate and sandstone (Dibblee and Ehrenspeck 1998). Unlike the situation on San Miguel Island, the upper contact is conformable with the Cozy Dell Shale (Weaver and Doerner 1969a). It may correlate to the Jolla Vieja Formation on Santa Cruz Island (Dibblee and Ehrenspeck 1998). Microfossils indicate a Ulatisian–early Narizian age, in the Middle Eocene (Dibblee and Ehrenspeck 1998).

Fossils found on Santa Rosa Island: The South Point Formation of Santa Rosa Island has yielded ostracodes, fish teeth, foraminifera (nine localities studied), and diatoms (Weaver and Doerner 1969a).

Fossils found elsewhere: On San Miguel Island, this formation has also yielded bivalves (Bremner 1933; Kies 1982), gastropods (Kies 1982), an articulated crab (Kies 1982), and coccoliths (Weaver and Doerner 1969a), It is also marked by general bioturbation (Kies 1982).

Cozy Dell Shale (Middle–Upper Eocene) (Tcd)
Description: The Cozy Dell Shale name was extended from the mainland to Santa Rosa Island and Santa Cruz Island for a thin Eocene shale unit. On Santa Rosa Island, it is found in the same general areas as the South Point Formation south of the Santa Rosa Island Fault, except not as close to the coast. In outcrop it is up to about 125 m (410 ft) thick, but somewhat thicker sections have been measured in wells, up to 183–195 m (600–640 ft) (Weaver and Doerner 1969a). It is composed of crumbly gray shale to siltstone, and weathers readily to rounded slopes (Dibblee and Ehrenspeck 1998). The upper contact with the Sespe Formation is disconformable (Weaver and Doerner 1969a).

The Cozy Dell Shale of CHIS was deposited in deep water. Foraminifera found in this unit at Santa Rosa Island indicate bathyal depths and cooling of the surface waters, down to perhaps a warm temperate range (Weaver and Doerner 1969a). On what is now the mainland, the depth was not so great, and the depositional setting has been compared to the modern Mississippi River delta front (Slatt and Thompson 1985). Foraminifera of the upper lower Narizian stage indicate a late Middle Eocene age, but fossils have not been found in the upper part of the formation (Weaver and Doerner 1969a).

Fossils found on Santa Rosa Island: The Cozy Dell Shale of Santa Rosa Island has yielded bivalves, foraminifera (five localities studied), and diatoms (Weaver and Doerner 1969a).

Fossils found elsewhere: On Santa Cruz Island, other fossils reported from this unit include a possible katsura seed, gastropods (Shapiro 1998), and coccoliths (Kies 1982), and the formation is marked by bioturbation (Kies 1982). On the mainland, other fossils include leaves, plant fragments, scaphopods (tusk shells), crabs, lobsters, asteroids (sea stars), ophiuroids (brittle stars), fish scales, and invertebrate burrows (Squires 1994).

Sespe Formation (Oligocene) (Ts)
Description: The Sespe Formation is well-known from the Santa Monica Mountains and Simi Valley on the California mainland, where it is part of a complex series of intertonguing terrestrial, shallow marine, and deep marine formations (Yerkes and Campbell 1979; Dibblee 1982b; Schwartz and Colburn 1987; Dibblee and Ehrenspeck 1993; Fritsche 1993). In CHIS, the Sespe Formation has only been definitely identified on Santa Rosa Island, although it may be present on San Miguel Island and Santa Cruz Island. The uppermost meter or so ("a few feet") of the Cozy Dell Shale on Santa Cruz Island and the basal beds of the Rincon Formation on San Miguel Island have been identified as potential exemplars of the Sespe Formation; fossil fragments have been found in the questionable beds on San Miguel Island (Weaver and Doerner 1969a). The Sespe Formation is found in a number of locations in southern and western Santa Rosa Island. It may be as much as 380 m (1,250 ft) thick on the island, although it can be difficult to distinguish from the overlying Vaqueros Formation. It is mostly composed of sandstone, with some siltstone, claystone, and conglomeratic beds. It is noted for its distinctive coloration, including layers of red, maroon, pink, and green (Weaver and Doerner

1969a). The upper contact with the Vaqueros Formation is conformable and, in some places, gradational (Avila and Weaver 1969).

The Sespe Formation on Santa Rosa Island has been interpreted as including a combination of terrestrial and marine rocks in a coastal setting. Some outcrops, particularly in western Santa Rosa Island, are thought to be braided stream or alluvial deposits, with red coloration suggesting a seasonal climate, whereas others in eastern Santa Rosa Island may be marine rocks (Woolley 1998). The presence of marine fossils in the upper part of the formation on the island (Weaver and Doerner 1969a) supports a partial marine origin. It is best known as a terrestrial formation on the mainland, with depositional settings including braided and meandering rivers, floodplain overbanks, salt marshes, and coastal environments (Bown 1994). Well cores from this formation taken beneath the Santa Barbara Channel include delta plain rocks (Miles and Rigsby 1990).

The age of the Sespe Formation on Santa Rosa Island is poorly constrained. "Vaquerosian" macrofossils in the upper part of the formation indicate a Zemorrian (=Oligocene) age for at least these beds (Weaver and Doerner 1969a). On the mainland, land mammal fossils in the formation indicate an age range including at least the Uintan (45.4–40 Ma) to the Arikareean (30.5–19 Ma) North American land mammal ages (NALMAs) for the main portion of the formation (Bown 1994), and a younger tongue of the formation is dated to the Hemingfordian (19–15.5 Ma) (Whistler and Lander 2003). A substantial hiatus occurred between 36 and 29.5 Ma (Prothero et al. 1996).

Fossils found on Santa Rosa Island: Unspecified macrofossils of "Vaquerosian" age have been found in upper beds (Weaver and Doerner 1969a). Jonathan Hoffman has found a pecten shell and a burrow in what may be this unit (pers. obs., June 2019).

Fossils found elsewhere: The Sespe Formation has a substantial assemblage of terrestrial fossils on the California mainland. Plants are represented by petrified wood and leaf impressions (Loel and Corey 1932). Invertebrates are represented by mollusks (Kelly et al. 1991) and trace fossils (Fritsche and Shmitka 1978). The non-mammalian vertebrate assemblage includes sharks, rays (Whistler and Lander 2003), frogs (Kelly et al. 1991), tortoises (Brattstrom 1961), soft-shelled turtles (Golz and Lillegraven 1977), lizards (Brattstrom 1955; Golz and Lillegraven 1977), snakes (Brattstrom 1955), crocodilians, and birds (Golz and Lillegraven 1977). More than 100 fossil mammal species from 35 families have been recognized in the Sespe Formation (Bown 1994). The following lists are not intended to be exhaustive for references, but to illustrate the breadth of mammal taxa. Sespe Formation mammals that are not carnivorans, perissodactyls (odd-toed ungulates), or artiodactyls (even-toed ungulates) include didelphid marsupials (opossums), several groups of insectivores, the extinct insectivore-like apatemyids and pantolestids, primates and their nearest relatives, several groups of rodents, rabbits and pikas, and extinct early carnivorous mammals (hyaenodonts and miacids) (Golz 1976; Golz and Lillegraven 1977; Kelly 1990; Bown 1994; Whistler and Lander 2003). Carnivorans are represented by bears (Wang et al. 2009), amphicyonids (beardogs), true dogs (including the extinct "bone crusher" borophagines), mustelids (weasels and allies), indeterminate cats (Whistler and Lander 2003), and nimravids (false saber-toothed cats) (Lander 1983). Perissodactyls include early tapir relatives (helatids and isectolophids), rhinoceroses (semiaquatic amynodonts, swift hyracodonts, and true rhinocerotids), brontotheres, and horses (Golz 1976; Golz and Lillegraven 1977; Bown 1994). Finally, artiodactyls are represented by hippo-like anthracotheres (Bown 1994), peccaries, pig-like entelodonts (Whistler and Lander 2003), a variety of small extinct deer-like ungulates (Golz 1976; Golz and Lillegraven 1977; Lander 1983, 2011), moschids (musk deer) (Whistler and Lander 2003), oreodonts and related agriochoerids (sheep-like artiodactyls), and camels (Bown 1994).

Vaqueros Formation (Lower Miocene) (Tv)

Description: The Vaqueros Formation was originally described on the California mainland and has a complex history as a term. It was originally defined and used as a biostratigraphic term based on marine invertebrate fossils (Miles and Rigsby 1990). Defining formations by fossils is no longer accepted, and the Vaqueros Formation is now limited to a difficult-to-define section of strata in coastal southern California (Dibblee and Ehrenspeck 1993; Fritsche 1993). Therefore, when examining the literature, it is necessary to know how the author is using the term "Vaqueros Formation" to prevent erroneous interpretations. Use of the biostratigraphic description "Vaquerosian" continues for fossil assemblages roughly equivalent to the old "Vaqueros Formation". The Vaqueros Formation is currently regarded as present on Santa Rosa Island and Santa Cruz Island of CHIS; as noted above in the San Miguel Island section, it also may be present on that island. However, Powell and Geiger (2019) noted that the "Vaqueros" of Santa Rosa Island and Santa Cruz Island differs lithologically from the Vaqueros Formation of the mainland and includes a fauna more like the "Temblor", and recommended that a new name be given.

The Vaqueros Formation of Santa Rosa Island includes gray sandstone, buff-weathering siltstone, mudstone, and local lenses of conglomerate (Avila and Weaver 1969). It is found mostly south of the Santa Rosa Island Fault, with two exposures north of it (Dibblee and Ehrenspeck 1998). It is up to 150 m (500 ft) thick in outcrop, and perhaps up to 300 m (1,000 ft) thick in total, according to well data (Avila and Weaver 1969). Avila and Weaver (1969) divided the formation into lower and upper sandstone members sandwiching a shaly middle member resembling the Rincon Formation, as can be seen in the GRI map (Figure 12). Other authors have questioned this (Dibblee and Ehrenspeck 1998; Woolley 1998); Dibblee and Ehrenspeck (1998) seem to have assigned the middle member to the Rincon Formation without explicitly stating this. The upper contact with the Rincon Formation is conformable. Together, the Vaqueros and Rincon formations of the island are essentially different facies of one subtropical to tropical inner shelf setting, with the water becoming deeper and cooler over time (Avila and Weaver 1969). The invertebrates found in this unit on the island indicate an Early Miocene age (Dibblee and Ehrenspeck 1998).

Fossils found on Santa Rosa Island: The island's Vaqueros Formation assemblage includes corals (Avila and Weaver 1969), bivalves, gastropods (Hertlein 1928; Loel and Corey 1932; Avila and Weaver 1969), worm tubes (Loel and Corey 1932), barnacles (Loel and Corey 1932), echinoids (Loel and Corey 1932; Grant and Hertlein 1938), invertebrate burrows (Dibblee and Ehrenspeck 1998), general bioturbation (Dibblee and Ehrenspeck 1998), and foraminifera (Patet 1972). There are also reworked Eocene-age coccoliths (McLean et al. 1976a). The recent sirenian discovery comes from a stratigraphically uncertain location that may pertain to the Vaqueros Formation or the Rincon Formation (Figure 13); it has been mapped as both at various times, but is lithologically more like the

Vaqueros Formation (J. Hoffman, pers. obs., June 2019). This site has yielded not only remains of two sirenians, but also bivalves, gastropods, barnacles, crabs, shark and ray teeth, and invertebrate burrows; similar fossils are found nearby, as well as a marine mammal bone (Hoffman 2017). Oysters and scallops have been identified as *Pycnodonte*? sp. and *Lyropecten* sp., respectively, and the invertebrate fauna suggest a middle to late Miocene age. Radiometric dating by the USGS may resolve the age of the sirenian site (J. Hoffman, pers. obs., January 2020).

Figure 13. The upper level of the sirenian site, with Jonathan Hoffman for scale (NPS/JUSTIN TWEET).

Several taxa have been named from this unit on the island. These include: the bivalves *Pecten miguelensis submiguelensis* (Loel and Corey 1932), *Ostrea loeli*, *O. wiedeyi*, and *Placunanomia granti*; the gastropods *Alectrion churchi*, *Calliostoma augustinensis*, and *Turritella tritschi* (Hertlein 1928); and the echinoids *Brissus kewi* and *Lytechinus coreyi* (Grant and Hertlein 1938). Avila and Weaver (1969) listed macrofossils from six localities. Fossils are particularly common in intervals of limy sandstone and mudstones (Avila and Weaver 1969). They are locally abundant enough to form "reefs" (Kew 1927; Loel and Corey 1932; Avila and Weaver 1969).

<u>Fossils found elsewhere</u>: The Vaqueros Formation of Santa Cruz Island has a similar assemblage, with a few other fossil groups represented including bryozoans, brachiopods, scaphopods, teeth of sharks and rays, possible cetaceans, and indeterminate vertebrate remains (Bereskin and Edwards 1969); see the "Vaqueros Formation" section under Santa Cruz Island below for more details. Outside of CHIS, the Vaqueros Formation has an even larger assemblage. Other marine single-celled and invertebrate organisms include radiolarians (another type of "shelled" protist), diatoms (Cushman and LeRoy 1938), crabs (Loel and Corey 1932; Squires and Fritsche 1978), and

ostracodes (Cushman and LeRoy 1938). Marine vertebrates are represented by pinnipeds (Loel and Corey 1932), the marine mammal *Desmostylus* (Squires and Fritsche 1978), cetaceans (Rivin 2010), and indeterminate bones (Squires and Fritsche 1978; Daniel-Lyle 1995). Terrestrial environments are represented by petrified and carbonized wood (Loel and Corey 1932), logs, palm fronds (Lander 2011), root traces, turtles, rhinoceroses, horses, entelodonts, camels, and indeterminate artiodactyls (Daniel-Lyle 1995).

Rincon Formation (Lower Miocene) (Tr)

Description: The Rincon Formation is present on Santa Rosa Island (Avila and Weaver 1969) and Santa Cruz Island (Bereskin and Edwards 1969), and as noted above may be present on San Miguel Island. This formation was often known as or included in the Temblor Formation in older publications on California geology (Patet 1972). On the California mainland, it is sometimes interpreted as the deep-water equivalent of the shallower-water Vaqueros Formation (Fritsche 1993). It represents a rapid deepening of depositional setting, due to subsidence (Isaacs 1983). Fossils on Santa Rosa Island indicate shallow water deposition at the beginning, and deepening water over time (Avila and Weaver 1969).

The Rincon Formation on Santa Rosa Island consists of shale, mudstone, claystone, and siltstone, with some fine-grained sandstone in the upper part. Thickness differs from place to place, from less than 270 m (900 ft) to more than 566 m (1,860 ft) (Avila and Weaver 1969). Avila and Weaver (1969) divided it into informal lower, middle, and upper members. It is found both north and south of the Santa Rosa Island Fault. As described by Avila and Weaver (1969), it has a complex gradational relationship with the underlying Vaqueros Formation and the Santa Rosa Island Volcanics, which in some places grade laterally into the Rincon Formation, and in others overlie or are vertically sandwiched by the Rincon Formation. Dibblee and Ehrenspeck (1998) eliminated some of this complexity by placing siliceous shale beds of the upper Rincon Formation into the Monterey Formation. The age of the Rincon Formation on the island can be constrained by dates of 19.3–18.1 Ma for the Santa Rosa Island Volcanics (Weigand and Savage 1999), and a strontium isotope date on a Rincon Formation bivalve of 20.5 ± 1.5 Ma (Weaver 1985). Compared to the Rincon Formation on Santa Cruz Island, the base is older and the upper part is younger on Santa Rosa Island (Avila and Weaver 1969).

Fossils found on Santa Rosa Island: The Rincon Formation is extensively fossiliferous on Santa Rosa Island. The fossil assemblage on the island includes carbonaceous debris, corals, bivalves, gastropods, echinoids, fish scales, bone fragments, foraminifera (Avila and Weaver 1969), and diatoms (Howell and McLean 1976). Mollusks are locally abundant enough to form “reefs” (Avila and Weaver 1969). Hertlein (1928) named two species of bivalves from the “Temblor Formation” of Santa Rosa Island: *Ostrea englekyi* and *Pteria rositae*. Avila and Weaver (1969) listed taxa from 27 macrofossil localities and 24 foraminifera localities. Reworked Eocene-age coccoliths have also been found (McLean et al. 1976a). As mentioned above in the “Vaqueros Formation” section, this unit may also be the host rock of the sirenian locality.

Fossils found elsewhere: On Santa Cruz Island, the Rincon Formation has yielded mostly microfossils, with no different groups from those on Santa Rosa Island.

Elsewhere, fossils known from the Rincon Formation but not yet reported from Santa Rosa Island include acritarchs (a "catch-all" classification for organic microfossils that cannot otherwise be classified) (Frederiksen 1995), coccoliths (Stanley et al. 1994), dinoflagellate algae (Finger 1983), tasmanitid algae, spores from pteridophytes (including clubmosses, spikemosses, and ferns), gymnosperm and angiosperm pollen (Frederiksen 1995), brachiopods (Squires and Fritsche 1978), scolecodonts (microscopic "jaws" of polychaete worms) (Frederiksen 1995), ostracodes (Finger 1983), holothurians (sea cucumbers) (Huddleston et al. 1986), sharks (Squires and Fritsche 1978), isolated cetacean bones (Squires and Fritsche 1978), and fecal pellets (Frederiksen 1995). Loel and Corey (1932) included a number of fossils in their Temblor Formation, but these are not necessarily all from the Rincon Formation.

Santa Rosa Island Volcanics (Lower Miocene) (Tsm)

Description: The Santa Rosa Island Volcanics are composed of dark basalt, lighter-colored dacite, and sedimentary rocks. They can be divided into three members: a lower clastic member, a middle intrusive member, and an upper basaltic flow member. The clastic member is up to 273 m (895 ft) thick and includes brown sandstones, siltstones, and shales. It is only found south of the Santa Rosa Island Fault. This member is associated with conglomerate and breccia of the San Onofre Breccia (Avila and Weaver 1969), and some authors include it in the Beechers Bay Formation (Dibblee et al. 1998; Nuccio and Woolley 1998). Originally, it was thought that all of the igneous rocks were intrusive (Kew 1927). Avila and Weaver (1969) re-evaluated the unit and identified it with the San Miguel Volcanics (as on Figure 12). Later, it was renamed the Santa Rosa Island Volcanics (Dibblee and Ehrenspeck 1998; Weigand and Savage 1999). The igneous rocks date from 19.3 to 18.1 Ma (Weigand and Savage 1999). Foraminifera in the clastic member indicate a slope setting under warm temperate waters; the sedimentary rocks may represent turbidites (Avila and Weaver 1969).

Fossils found on Santa Rosa Island: The clastic member is fossiliferous, having yielded the bivalve *Spondylus perrini* and foraminifera (Avila and Weaver 1969). Avila and Weaver (1969) provided taxa lists for 13 foraminifera localities.

Fossils found elsewhere: This collective unit is limited to Santa Rosa Island.

San Onofre Breccia (Lower–Middle Miocene) (Tso)

Description: The San Onofre Breccia is a distinctive blue conglomeratic unit, first mapped on the California mainland. The source of the distinctive sediment is a rock unit called the Catalina Schist, found to the north and northwest (Schwartz and Colburn 1987). On Santa Rosa Island the breccia is represented by a single outcrop area on the north-central shore, extending offshore. There the unit is composed of massive conglomerate and interbedded sandstone and siltstone over an interval of gray tuff and tuffaceous siltstone, resting on the Rincon Formation. It is approximately 210 m (700 ft) thick (Avila and Weaver 1969). The conglomerate includes a variety of volcanic and metamorphic rock fragments (Avila and Weaver 1969; Dibblee and Ehrenspeck 1998). Avila and Weaver (1969) associated it with the clastic member of the Santa Rosa Island Volcanics, but other authors have considered it part of the Beechers Bay Formation (Nuccio 1977; Dibblee and Ehrenspeck 1998; Nuccio and Woolley 1998). A volcanic clast from the breccia has been dated to approximately 15.8

Ma (Chinn and Weigand 1994). The presence of marine fossils on nearby Santa Cruz Island shows that at least some of the unit is marine in origin (Dibblee and Ehrenspeck 1998).

Fossils found on Santa Rosa Island: None to date.

Fossils found elsewhere: The San Onofre Breccia on Santa Cruz Island has yielded bivalves, barnacles, foraminifera (Bereskin and Edwards 1969), and reworked Paleocene or Cretaceous bivalves and Paleocene gastropods (Stuart 1976). Outside of CHIS, the San Onofre Breccia has also preserved bones of pinnipeds and cetaceans (Woodford 1925).

Beechers Bay Formation (Lower–Middle Miocene) (Tmbt)

Description: The Beechers Bay Formation of Santa Rosa Island was first tentatively identified as the Santa Margarita Formation, a formation found on the mainland (Kew 1927). Avila and Weaver (1969) renamed it as the Beechers Bay Member of the Monterey Formation. Because it is lithologically distinct from the typical Monterey Formation, more recent authors have preferred to describe it as a formation in its own right (Nuccio 1977; Dibblee and Ehrenspeck 1998; Nuccio and Woolley 1998; Weigand and Savage 1999; Weigand et al. 2002). To further complicate the nomenclatural situation, the Beechers Bay Formation is considered to be equivalent to the Blanca Formation on Santa Cruz Island (Dibblee 1982a), and some authors prefer to extend the Blanca name to Santa Rosa Island (Howell and McLean 1976).

The Beechers Bay Formation is heterogeneous, with three major rock types: tuffaceous rocks, sandstone and shale, and conglomerate. The tuffaceous rocks are found low in the member, and the conglomeratic facies is found toward the top (Avila and Weaver 1969). Nuccio and Woolley (1998) recommended dividing it into five informal members, from A at the base to E at the top, including the San Onofre Breccia at the base as Member A. They described the different members as different settings on a deep-sea fan near an active volcanic source, which they suspected was near Santa Catalina Island (Nuccio and Woolley 1998). Faulting since the Miocene would have separated the source from the deposits (Dibblee and Ehrenspeck 1998). On Santa Rosa Island, the middle Beechers Bay Formation includes early and middle Luisian foraminifera (Weigand and Savage 1999).

Fossils found on Santa Rosa Island: Determining which reported fossils come from the Beechers Bay Formation is hindered by how authors divide the Miocene rocks. Avila and Weaver (1969) noted that fossils were present in outcrops of the Monterey Formation in southeastern Santa Rosa Island which could be considered the Beechers Bay Member, but which grade immediately into the shale member. For cartographic purposes these rocks were mapped as the shale member, but the authors seem to regard at least some of them as actually belonging to the Beechers Bay Member later in the text (p. 66). They cited a small number of foraminifera taxa from these rocks, which other authors identified as the Beechers Bay Formation (Nuccio 1977; Nuccio and Woolley 1998; "C" division of Weigand and Savage 1999). No one collection of foraminifera cited in Figure 11 of Avila and Weaver (1969) exactly corresponds to the taxa in the text, so for this report the species they specifically cited in the text were included in Appendix A under the Beechers Bay Formation, while the species cited in the collections in the figure were included under the shale member of the Monterey Formation. The formation has also produced the bivalve *Spondylus perrini* (Avila and Weaver 1969). Fossils are rare in the unit, and are limited to the middle portion; reworked bivalve fragments are also present (Avila and Weaver 1969). Howell and McLean (1976) reported invertebrate burrows and foraminifera in a volcaniclastic unit exposed south of Carrington Point they assigned to the Blanca Formation (see the Santa Cruz Island section); the geologic map used for this inventory maps this area as the Beechers Bay Formation.

Fossils found elsewhere: The Beechers Bay Formation of San Miguel Island has yielded brachiopods (Weaver and Doerner 1969b) and bivalves (Bremner 1933; Weaver and Doerner 1969b). On Santa Cruz Island, bivalves, barnacles, and foraminifera have been reported (Bereskin and Edwards 1969).

Monterey Formation (shale member) (Lower–Middle Miocene) (Tmsh)

Description: The Monterey Formation of Santa Rosa Island, as represented by the shale member (see the "Monterey Formation" section under "San Miguel Island Geology" for more details), has a complex relationship with the Beechers Bay Formation. As reported by Avila and Weaver (1969), "the shale can occur stratigraphically below, within, and above the coarser clastic Beechers Bay Member," which they interpreted as tracing fluctuating sediment supply and energy of deposition. This intermingling of facies can make mapping difficult. The lower extent of the formation is also debated. Dibblee and Ehrenspeck (1998) included part of the upper Rincon Formation as mapped by Sonneman et al. (1969) in the Monterey Formation, which makes the Santa Rosa Island Volcanics interrupt the Monterey Formation. The shale member of Santa Rosa Island was originally assigned to the Modelo Formation (Kew 1927; Avila and Weaver 1969). It is a light-colored silica-rich shale, with foraminifera corresponding to outer shelf and upper slope settings (Avila and Weaver 1969).

Fossils found on Santa Rosa Island: On Santa Rosa Island, the shale member has yielded bivalves and foraminifera, and is generally diatomaceous (although specific taxa have not been identified) (Avila and Weaver 1969). Avila and Weaver (1969) listed taxa from two bivalve localities and 12 foraminifera localities in the shale member. Howell and McLean (1977) reported diatomite rocks of middle Miocene age on the island, best fitting the shale member of the Monterey Formation.

Fossils found elsewhere: The shale member of the Monterey Formation on San Miguel Island has yielded bivalves, foraminifera, and diatoms (Weaver and Doerner 1969b). On Santa Cruz Island, it has yielded bivalves, gastropods (Rand 1931, 1933; Weaver and Meyer 1969), fish scales and bones (Weaver and Meyer 1969), an unnamed desmostylian (Barnes and Aranda-Manteca 1997; Domning and Barnes 2007), cetacean bones (Weaver and Meyer 1969), foraminifera (Weaver and Meyer 1969), and diatoms (Rand 1931; Weaver and Meyer 1969).

Quaternary rocks and sediments (Pleistocene–Holocene)

Description: The Quaternary sediments of Santa Rosa Island include a variety of fossiliferous marine and terrestrial sediments. Some of the sedimentary sequences, such as the island's dunes, include fossils as part of their basic lithological makeup. Many of the dune sediments include carbonate minerals derived from sand-sized fragments of older fossil invertebrates (Muhs et al. 2018). Another significant source of fossils is the marine terraces. Orr (1960) identified seven subaerial and five submarine terraces, with a vertical range of 400 m (1,300 ft). He named the Santa Rosa Formation for the sediments on the lowest subaerial terrace and the three wave-cut platforms below, and designated three members within the formation. From his original description, the oldest is the Garañon (or Garanon) Member, associated with the 8 m (25 ft) Garañon platform. A sea-level rise followed, cutting the 23 m (75 ft) Fox platform and depositing the sediments of the Fox Member. Finally, the Tecolote Member was deposited over both platforms and associated sediments during a lowstand, from some time before 30,000 radiocarbon yr BP to at least 10,400 ± 2,000 radiocarbon yr BP (17,400–7,430 cal yr BP) (Orr 1960). Orr (1968) gave the age of the Garañon Member as more than 200,000 years old and the Fox Member as approximately 135,000 years old. More recent work indicates that Orr's dating and order of units are incorrect. The Tecolote Member is still regarded as the youngest, dated to 12,500 radiocarbon yr BP (Collins et al. 2018a), but the Garañon Member is actually the middle member and approximately 80,000 years old, and the Fox Member is the oldest and approximately 125,000 years old (Muhs et al. 2014, 2015). Orr's names have not achieved wide usage, but are occasionally seen in publications, and are used here as used in these publications for convenience. The long record of human presence on the island, beginning with Arlington Man, led Barnosky et al. (2014) to invoke Santa Rosa Island when proposing a new North American Land Mammal Age, the Santarosean. This NALMA encompasses the period of time after humans became established in North America south of 55°N, but before the establishment of Europeans and their domestic mammals in the 1500s.

Fossils found on Santa Rosa Island: Diverse terrestrial and marine fossils have been recovered from the Quaternary rocks and deposits of Santa Rosa Island. Plants are best known from various palynomorphs (spores of mosses, spikemosses, and ferns, and pollen of conifers and angiosperms) (Cole and Liu 1994; Anderson et al. 2010). Cole and Liu (1994) reported on palynomorphs representing the past 5,200 years; this work was used to show changes in aridity, erosion, and throughflow. Their site was revisited by Anderson et al. (2010), which also incorporated a somewhat longer palynomorph record from another site. The palynomorphs show that the island had a coastal conifer forest at the end of the Pleistocene, replaced at approximately 11,800 cal yr BP by grassland and scrub as the climate warmed (Anderson et al. 2010). Other microfossils reported by Anderson et al. (2010) include charcoal fragments, phytoliths (silica secreted in plant cells), sponge spicules, diatoms, radiolarians, and somatocysts of chrysophytes (golden algae). Macroscopic plant remains from the island include seeds (Erlandson et al. 1999), calichified root and tree casts (Orr 1960), reed casts (Orr 1962), the cypress *Cupressus goveniana* (Johnson 1977), and pine and cherry wood (R. S. Anderson, pers. comm., April 2020). Petrified wood is found sporadically on the island (J. Tweet, pers. obs., June 2019) and is most likely of Pleistocene age, given that most of the pre-Pleistocene formations of the island are marine. Non-petrified end-Pleistocene pine and cherry wood is present in the northwestern side of the island, and descriptions of additional palynomorph and charcoal records are underway (R. S. Anderson, pers. comm., April 2020).

Santa Rosa Island has many Quaternary invertebrate fossils, from both marine and terrestrial settings. The assemblages include corals (Muhs et al. 2014, 2015), chitons, bivalves, gastropods, barnacles (Orr 1960; Muhs et al. 2014), freshwater ostracodes (Schumann et al. 2016), echinoids (Orr 1960; Muhs et al. 2014), and trace fossils, such as rocks bored by mollusks (Kew 1927), and arthropod fecal material (Scott et al. 2017). Scott et al. (2010, 2017) regarded arthropod fecal material as the true identity of carbonaceous elongates interpreted as evidence for a Younger Dryas impact (Kennett et al. 2008). Similarly, they interpreted the carbon spherules as fungal fragments (Scott et al. 2010, 2017). Pinter et al. (2011) provided several dates on charcoal and charred wood in relation to the Younger Dryas studies.

The Quaternary vertebrate assemblage of the island is similar to that of San Miguel Island. Vertebrate fossils are best known from fluvial sediments on the northwestern side of the island (Guthrie 1998). A small number of ray-finned fish taxa are known from archeological contexts dating throughout the Holocene (Erlandson et al. 1999, 2011). Amphibians are represented by the salamander *Batrachoseps* (Mead et al. 2004) and chorus frogs (Mead et al. 2018). Reptiles are represented by alligator lizards (Erlandson et al. 1999) and rattlesnakes (Guthrie 1998). A substantial avifauna is known from the island, albeit not as large as that of San Miguel Island. Orr collected 167 bones, which were identified by Hildegard Howard in the 1960s. Further collections were made in 1987 and 1991 in northwestern Santa Rosa Island, producing a number of new specimens; the most significant site was a long-term owl roost used during the late Pleistocene and early Holocene (Collins et al. 2018a). The avifauna includes anseriforms, podicipediforms, procellariiforms, suliforms, charadriiforms, cathartiforms, accipitriforms, falconiforms, columbiforms, strigiforms, piciforms, and passeriforms (Collins et al. 2018a). The extinct owl *Asio priscus* was named from a specimen found on Santa Rosa Island (Howard 1964b).

Most Quaternary mammal specimens from the island pertain to terrestrial species. These include ornate shrews (Guthrie 1998), voles (Mead et al. 2004), the giant deer mouse *Peromyscus nesodytes* (Wilson 1936; Guthrie 1998), island foxes (Orr 1968; Rick et al. 2009), dogs (Rick et al. 2008), and the mammoths *M. columbi* and *M. exilis* (Figure 14) (Agenbroad 2012; Muhs et al. 2015; Pigati et al. 2017; see under the "Taxonomy" section for more details on the mammoths). Sea mammals are represented by seals, sea lions (Orr 1968), the sea otter *Enhydra lutris* (Mitchell 1966), and whales (Stock and Furlong 1928; Stock 1935; Orr 1968). A single whale vertebra has been found near the base of the Quaternary sediment (Stock and Furlong 1928; Stock 1935), and a scattered partial whale skeleton was uncovered from the marine sediments of the Garañon Member over a period of years beginning in 1946 (Orr 1968). Most of these mammals lived at the end of the Pleistocene (Guthrie 1998), although the fox and dog remains are Holocene. Orr (1968) reported an island fox skull in the late Pleistocene-age upper Tecolote Member, but it was later found that this "Pleistocene" specimen dated to the late Holocene (Shelley 2001; Rick et al. 2009). Most of the island fox remains on the island were found during excavation of cemetery sites (Collins 1991). *Peromyscus nesodytes* was named from Santa Rosa Island (Wilson 1936). Thousands of bones of this rodent are known from the island, with thousands alone associated with the site that yielded the remains of Arlington Man (Orr 1962, 1968). Orr attributed abundant mouse bones a bog (Orr 1968), but they are actually part of a long-term deposit of barn owl pellets (Guthrie 1998; Collins et al. 2018a). Owls lived at this site between 28,240 ± 940 radiocarbon yr BP (34,120–30,720 cal yr BP) and 10,240 ± 180 radiocarbon yr BP (12,540–11,330 cal yr BP). Animals represented in these pellets include snakes, shrews, and *Peromyscus nesodytes*; many of the pellets are burned, showing fire events (Guthrie 1998). One of the few fossils of the Island Scrub Jay (*Aphelocoma insularis*) was found here (Collins 2009; Collins et al. 2018a).

Figure 14. A lower jaw of a mammoth calf from Santa Rosa Island in LACM collections (NPS/JUSTIN TWEET).

In addition, Santa Rosa Island has yielded the oldest well-dated human remains in the National Park Service and North America in the form of Arlington Man, recovered in 1959 (Figure 15). This individual is known from two femurs, a humerus, and an unknown bone (Orr 1968). Originally, the bones were identified as male (Orr 1962). For a short time, they were re-evaluated as female (Wisner 1999; Agenbroad et al. 2005; Dandridge 2006), but it now appears that the individual was male after all (Chawkins 2006). Bone collagen provides a date of 10,960 ± 80 radiocarbon yr BP (13,010–12,710 cal yr BP) (Agenbroad et al. 2005), but the collagen is degraded, and the person is probably slightly older, being bracketed by charcoal dates of 11,580 ± 45 radiocarbon yr BP (13,494–13,291 cal yr BP) and 11,250 ± 40 radiocarbon yr BP (13,194–13,049 cal yr BP) (Dandridge 2006).

Figure 15. The canyon wall at the Arlington Man site as of June 2019, with a field book for scale (NPS/JUSTIN TWEET).

Per Orr (1960, 1968), the Garañon and Fox members both include lower marine facies and upper terrestrial facies. The marine facies of the Garañon Member has yielded chitons, bivalves, gastropods, echinoids, and bones of shore birds, sea lions, sea otters, pygmy mammoths, and whales. The terrestrial facies of the Garañon Member has bones of *Peromyscus* and pygmy mammoths, and weathered fragments of reworked Miocene-age bivalves (*Ostrea*) and gastropods (*Turritella*). The marine facies of the Fox Member has yielded chitons, bivalves, gastropods, barnacles, and echinoids, while the terrestrial facies of the member has yielded root casts, tree casts, gastropods, and pygmy mammoth bones. Pleistocene marine sediments at the 76 m (250 ft) level have also yielded bivalves and gastropods (Orr 1960, 1968).

<u>Fossils found elsewhere</u>: The Quaternary fossil record of Santa Rosa Island is probably most similar to that of San Miguel Island at this time, but further exploration of Santa Cruz Island would likely show that all three have very similar assemblages.

Santa Cruz Island Geology

Santa Cruz Island is bisected by the east-west Santa Cruz Island Fault, and there are distinct stratigraphic sequences on either side of the fault. On the north, the geology is limited to Quaternary rocks, the Monterey Formation, and the Santa Cruz Island Volcanics. The land south of the fault has a much longer record, including all of the island's outcrops of pre-Miocene rocks, the Rincon Formation, the San Onofre Breccia, and the Blanca Formation (Dibblee 1982a; Weigand and Savage 1999). The fault has a history of infrequent large earthquakes (Pinter et al. 1998).

Units exposed on Santa Cruz Island include the following, in ascending order (lowest to highest, oldest to youngest): Santa Cruz Island Schist and Willows Plutonic Complex (Middle–Upper Jurassic); Alamos Tonalite (Lower Cretaceous); Pozo Formation (Upper Paleocene–Lower Eocene); Cañada Formation (Lower–Middle Eocene); Jolla Vieja Formation and Cozy Dell Shale (Middle–Upper Eocene); Vaqueros Formation (Oligocene–Lower Miocene); Rincon Formation (Lower Miocene); San Onofre Breccia, Santa Cruz Island Volcanics, Beechers Bay Formation, and Monterey Formation (Lower–Middle Miocene); Blanca Formation (Middle Miocene); Potato Harbor Formation and Middle Anchorage Alluvium (Pleistocene); and younger Quaternary rocks and sediments (Pleistocene–Holocene) (Weaver and Nolf 1969; Dibblee and Minch 2001a, 2001b) (Figure 16, Table 3). Most but not all of these units are fossiliferous. Alternative names have been used for some of these formations, and are discussed below.

In addition to the surficial exposures, there are several lengthy well records mentioned in the literature that include fossils, but the rocks have not been definitively correlated to the rocks exposed at the surface. For this reason, and because fossils found several hundred meters or feet below the surface are of limited import for management, the well records are only mentioned briefly, except for the fossiliferous Cretaceous rocks which are only found in the well cores (see below). The wells include the Richfield Santa Cruz Island No. 1 and No. 2 and the Union Gherini Well 1, not to be confused with the Gherini 1 well (also known as the Santa Cruz Expl. 1 well, also on Santa Cruz Island). Records for these wells can be accessed using the well finder system at https://www.conservation.ca.gov/dog/Pages/WellFinder.aspx. Because of their limited diameters, well cores are not ideal for producing complete macrofossils, but often include microfossils and partial macrofossils. For example, apart from Cretaceous microfossils mentioned in the literature, well data shows that the Richfield No. 2 core also included mollusk fragments and a fish scale resembling those of the extinct Miocene drumhead *Lompoquia*.

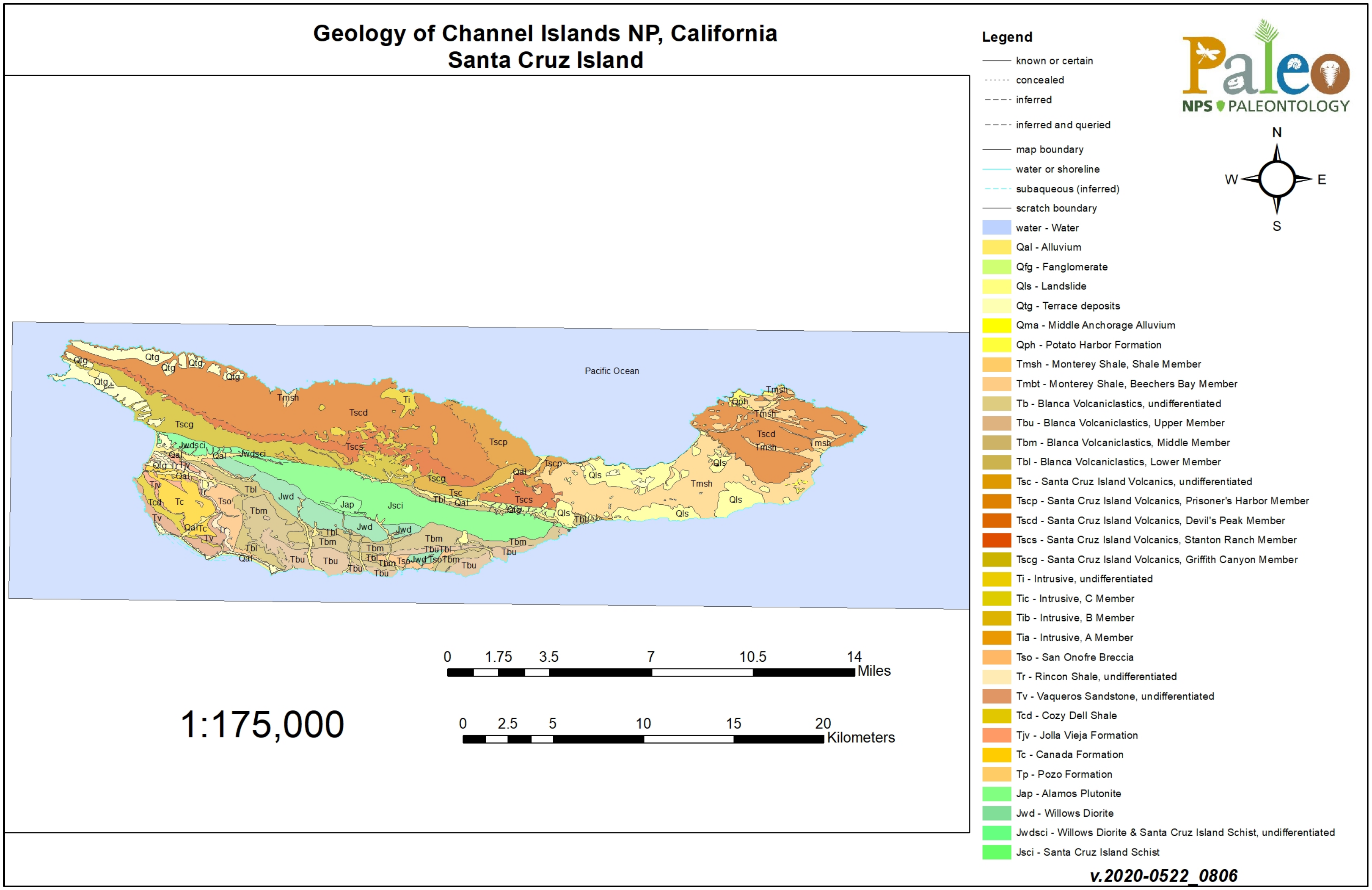

Figure 16. Geological map of Santa Cruz Island derived from Weaver and Nolf (1969), digitized by the NPS GRI. Digital map data is available at https://irma.nps.gov/DataStore/Reference/Profile/2244142.

Table 3. Summary of Santa Cruz Island stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. Details and references can be found in the text and in Tweet et al. (2012).

Formation	Age	Fossils Found on Santa Cruz Island	Depositional Environment
Unnamed Quaternary rocks and sediments	Pleistocene–Holocene	Mosses, conifers, flowering plants, palynomorphs, undetermined plant remains, corals, bivalves, gastropods, diplopods, freshwater ostracodes, insects, undetermined invertebrates, canids, mammoths, small vertebrates, arthropod coprolites, and fungal remains	Shallow marine to terrestrial settings
Middle Anchorage Alluvium	Pleistocene	Bivalve borings	Beach and alluvium
Potato Harbor Formation	Pleistocene	Root casts, bryozoans, bivalves, gastropods, undetermined mollusks, barnacles, echinoids, shell fragments, foraminifera, and unspecified “algae”	Beginning as shallow marine, becoming eolian beach
Blanca Formation	Middle Miocene	Undetermined fossils?	Nearshore marine volcanic and submarine fan complex
Monterey Formation (shale member)	Early–Middle Miocene	Bivalves, gastropods, fish scales and bones, desmostylians, cetaceans, foraminifera, and diatoms	Outer shelf to slope, becoming deeper over time
Beechers Bay Formation	Early–Middle Miocene	Bivalves, barnacles, and foraminifera	Middle shelf to middle slope, with deposition by turbidity currents
Santa Cruz Island Volcanics	Early–Middle Miocene	Cetaceans and foraminifera	Volcanic flows, beginning subaerially and becoming subaqueous over time
San Onofre Breccia	Early–Middle Miocene	Bivalves, gastropods, barnacles, foraminifera	Inner to middle continental shelf, with brackish and shallow marine fauna
Rincon Formation	Early Miocene	Bivalves, gastropods, ctenoid fish scales, foraminifera, and undetermined fossils	Middle to outer continental shelf
Vaqueros Formation	Oligocene–Early Miocene	Bryozoans, brachiopods, bivalves, gastropods, scaphopods, barnacles, echinoids, ray and shark teeth, a possible whale bone, undetermined vertebrates, invertebrate burrows, foraminifera, undetermined fossils, and reworked Paleogene fossils	Continental shelf
Cozy Dell Shale	Middle–Late Eocene	A possible katsura seed, bivalves, gastropods, bioturbation, coccoliths, and foraminifera	Marine, beginning as continental slope and reaching abyssal depths as basin subsided
Jolla Vieja Formation	Middle–Late Eocene	Bivalves, gastropods, and possibly foraminifera	Submarine fan

Table 3 (continued). Summary of Santa Cruz Island stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. Details and references can be found in the text and in Tweet et al. (2012).

Formation	Age	Fossils Found on Santa Cruz Island	Depositional Environment
Cañada Formation	Early–Middle Eocene	Wood casts, corals, bivalves, nautiloids, gastropods, undetermined mollusks, annelid worm tubes, echinoids, shell debris, ray teeth, invertebrate burrows and bioturbation, foraminifera, coccoliths, and undetermined fossils	Marine, outer shelf to inner slope depths with submarine fan settings
Pozo Formation	Late Paleocene–Early Eocene	Bivalves, gastropods, undetermined mollusks, annelid worm tubes, invertebrate burrows and bioturbation, foraminifera, coccoliths, and undetermined fossils	Marine, beginning as continental shelf and becoming deeper
Upper Cretaceous rocks (subsurface)	Late Cretaceous	Foraminifera	Marine
Alamos Tonalite	Early Cretaceous	Unfossiliferous (intrusive igneous rocks)	Not applicable (igneous rocks that solidified at depth)
Willows Diorite	Middle–Late Jurassic	Unfossiliferous (intrusive igneous rocks)	Not applicable (igneous rocks that solidified at depth)
Santa Cruz Island Schist	Middle–Late Jurassic	None to date; fossils are unlikely because of metamorphism	Metamorphosed sedimentary, volcanic, and intrusive rocks associated with a submarine volcanic complex

Geologic Formations

Santa Cruz Island Schist (Middle–Upper Jurassic) (Jsci)

Description: The Santa Cruz Island Schist is regarded as the oldest rock unit exposed in CHIS. It is found on the ridge south of Cañada del Medio, cropping out in a band 16 km (10 mi) long and 2.4 km (1.5 mi) wide, truncated by the Santa Cruz Island Fault. It is olive-green or gray-green when freshly exposed, weathering to red when oxidized. It is heavily faulted as well as intruded by the Alamos Plutonite. The original rocks are thought to have been mostly basaltic flows with some thin-bedded siltstone, sandstone, and limestone (Weaver 1969a). Hill (1976) interpreted the original setting as a volcanic pile. The age of the schist is not known directly, but it is thought to be comparable in age to the Willows Diorite, which is dated to approximately 162 Ma (Mattinson and Hill 1976).

Fossils found on Santa Cruz Island: Unfossiliferous (Weaver 1969a); as a high-grade metamorphic unit derived primarily from volcanic rocks, it is unlikely to have fossils.

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Willows Diorite (Middle–Upper Jurassic) (Jwd)

Description: The Willows Diorite, sometimes called the Willows Plutonic Complex, is a notably heterogeneous intrusive igneous unit. In particular, parts of it are composed of very coarsely crystalline hornblendite (rich in the mineral hornblende), adjacent to medium-grained diorite. Igneous dikes cut through the larger igneous bodies (Weaver 1969a). Hill (1976) proposed that "Willows Plutonic Complex" would be more appropriate because of the heterogeneity, and suggested that it is composed of more than one pluton. Outcrops are covered by a yellowish-tan thin rubble of fragments. There are two main areas of outcrops: the main area flanks the Santa Cruz Island Schist on its south side for much of its length, and a smaller second body is found southeast, north of Willows Anchorage and south of the Willows Fault (Weaver 1969a). The Willows Diorite was initially interpreted as younger than the Alamos Plutonite (Rand 1933; Weaver 1969a); the structural relationships are difficult to observe, and the Willows Diorite is less metamorphosed than the Alamos Plutonite (Weaver 1969a). However, Mattinson and Hill (1976) reported a date of approximately 162 Ma for the Willows Diorite versus a 141 Ma date for the Alamos Plutonite, and Howell et al. (1976) observed that the Alamos Plutonite locally intrudes the Willows Diorite, and suggested that the diorite metamorphosed the schist.

Fossils found on Santa Cruz Island: Unfossiliferous (intrusive igneous rocks).

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Alamos Plutonite (Lower Cretaceous) (Jap)

Description: Also known as the Alamos Tonalite or Alamos Diorite, this unit is composed of light gray quartz-rich coarsely crystalline and somewhat metamorphosed intrusive igneous rocks, weathering light greenish gray (Weaver 1969a). "Diorite" and "tonalite" are similar types of intrusive igneous rocks, differing in that diorite is less than 20% quartz and tonalite is more. This unit intrudes the central Santa Cruz Island Schist (Weaver 1969a). As noted, it was previously thought to be older than the Willows Diorite, but is now known to date to the Early Cretaceous, versus a basal Late Jurassic date for the Willows Diorite (Mattinson and Hill 1976).

Fossils found on Santa Cruz Island: Unfossiliferous (intrusive igneous rocks).

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Upper Cretaceous rocks (subsurface) (Upper Cretaceous)

Description: Although Upper Cretaceous rocks are occasionally identified on Santa Cruz Island (Dibblee 1982a), they are only definitely known from the subsurface. Cretaceous rocks have been identified in two wells on opposite sides of the Santa Cruz Island Fault in the western part of the island (Richfield Santa Cruz Island No. 1 and No. 2) (Doerner 1969; Weaver 1969b; Howell et al. 1976; Gordon et al. 2001). In Richfield No. 2, south of the fault, the lower 567 m (1,860 ft) are interpreted as Upper Cretaceous, based on the presence of the foraminifera *Globotruncana arca*. Above these sandstones and conglomerates are siltstones and sandstones with fragments of the Paleocene gastropod *Turritella pachecoensis* (Doerner 1969). The Cretaceous rocks are similar to the Jalama Formation of San Miguel Island (Doerner 1969), and Gordon et al. (2001) explicitly identified the subsurface unit as the Jalama Formation.

Fossils found on Santa Cruz Island: Foraminifera (Doerner 1969).

Fossils found elsewhere: If this unit is like the Jalama Formation of San Miguel Island, bivalves (Bartling and Abbott 1983) and coccoliths (Bartling and Abbott 1983; Miller 1983, 1985) may also be present.

Pozo Formation (Upper Paleocene–Lower Eocene) (Tp)

Description: The Pozo Formation is found only in southwestern Santa Cruz Island (Doerner 1969), although the unit known informally as the undifferentiated Pozo–Cañada Formation on San Miguel Island is thought to correlate to part of it (Weaver and Doerner 1969a). The Pozo Formation may be as much as 140 m (450 ft) thick (Dibblee 1982a), but only 70 m (225 ft) are exposed (Doerner 1969). It is a buff-colored unit mostly composed of arkosic sandstone and siltstone, with some shale. The upper contact with the Cañada Formation is disconformable, and includes some shallow paleochannels less than a meter or yard in depth. The hiatus was probably of short duration (Doerner 1969). Before it was named, the rocks now included in the Pozo Formation had been included in the Martinez Formation (Bremner 1932; Doerner 1969), another of the biostratigraphically defined units formerly in wide use in California.

The Pozo Formation was deposited during the Late Paleocene to Early Eocene. It has been dated to the Bulitian (approximately 56.7–54.7 Ma) and possibly latest Ynezian (approximately 60.3–56.7 Ma) stages (Doerner 1969). Fossils from this formation indicate a relatively shallow marine setting, perhaps on the inner continental shelf, under tropical to semitropical waters; depth increased near the end of deposition, putting the area in an outer shelf to inner slope location (Doerner 1969). Kies and Abbott (1982) interpreted the formation as storm-ebb deposits.

Fossils found on Santa Cruz Island: The Pozo Formation is fossiliferous on Santa Cruz Island, including bivalves, gastropods (Rand 1931, 1933; Doerner 1969; Shapiro 1998), sabellariid worm tubes (Shapiro 1998), invertebrate burrows and bioturbation (Kies 1982), coccoliths (Kies 1982), and foraminifera (Doerner 1969). Fossils are locally abundant enough to form reefs (Bremner 1932; Doerner 1969). There is a bed less than a meter (1–2 ft) thick near the base of the exposed section with abundant mollusks, particularly the gastropod *Turritella*, which is found in such numbers that the bed is sometimes called a *Turritella* reef (Doerner 1969). The turritellas can be of great size (greater than 20 cm/7.9 in) (Gordon et al. 2001). The bivalve *Ostrea* is also sometimes found in thin, reef-like accumulations. Mollusks are found throughout the unit, and are often the nuclei of concretions in the sandstone beds (Doerner 1969). Near the top of the formation is an interval with a distinct mollusk assemblage and frequent worm tubes. This interval continues upward into the basal Cañada Formation (Shapiro 1998). Sparse, poorly preserved foraminifera have been found in the formation's siltstone and shale; Doerner (1969) listed examples from six locations. Squires and Saul (2002) reported and figured a specimen of the gastropod *Corsania* (*Januncia*) *janus* from this formation on the island. Hertlein (1933) named the bivalve species *Ostrea haleyi* from the "Domengine Formation" on the island; a recent review indicated that the specimen was found in the Pozo Formation (Squires 2018), not the Cañada Formation as sometimes reported (Moore 1987).

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Cañada Formation (Lower–Middle Eocene) (Tc)

Description: The Cañada Formation is composed of gray to blue-gray shale, siltstone, and less abundant thin beds of limestone and sandy limestone, exposed in a roughly elliptical area of southwestern Santa Cruz Island (Doerner 1969). Similar rocks on San Miguel Island are included in the undifferentiated Pozo–Cañada Formation (see above). It is the most widely distributed Paleogene unit on Santa Cruz Island (Doerner 1969). Doerner (1969) gave its thickness as about 430 m (1,400 ft), but Dibblee (1982a) cited 650 m (2,100 ft). The formation is coarsest near the base. The lowest meter or yard includes basal conglomerates filling channels cut into the Pozo Formation, and the next 15 m (50 ft) is a sandstone-siltstone interval. The upper contact with the Jolla Vieja Formation is conformable (Doerner 1969). The Cañada Formation and overlying Eocene formations were formerly included in the Domengine Formation (Rand 1931, 1933; Bremner 1932), another biostratigraphic formation.

The Cañada Formation is another marine unit, and its fossils show continuation of the deepening trend begun near the end of the underlying Pozo Formation. Deposition began in an outer shelf or upper slope setting, which progressively deepened to possibly a lower slope setting by the close of the formation (Doerner 1969). The formation's foraminifera illustrate eight short-lived shallowing events (Molesworth and Sloan 1998). The foraminifera range in age from the Bulitian to the early Narizian stages (between approximately 56.7 and about 42 Ma) (Doerner 1969). Submarine fan deposition also occurred during the marine transgression (Kies and Abbott 1982), and gravelly layers left by storm surges can be found in the basal part of the formation (Abbott et al. 1983).

Fossils found on Santa Cruz Island: The Cañada Formation of Santa Cruz Island has wood casts, corals (Shapiro 1998), bivalves (Bremner 1932; Doerner 1969; Shapiro 1998), nautiloids (Shapiro 1998), gastropods (Bremner 1932; Shapiro 1998), sabellariid worm tubes, echinoids, ray teeth (Shapiro 1998), invertebrate burrows and bioturbation (Kies 1982), coccoliths (Doerner 1969; Kies 1982), and foraminifera (Doerner 1969; Molesworth and Sloan 1998). Doerner (1969) listed taxa from eight coccolith and 25 foraminifera localities, and Molesworth and Sloan (1998) provided additional data on the formation's foraminifera. Macrofossils are diverse, but not abundant (Shapiro 1998).

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Jolla Vieja Formation (Middle–Upper Eocene) (Tjv)

Description: The Jolla Vieja Formation is found only in southwestern Santa Cruz Island. This formation has significant variation in thickness and lithology, with different localities documented as 26 m (85 ft) thick and mostly sandstone and 270 m (880 ft) thick (and truncated by faulting) and almost entirely composed of conglomerate. Siltstone and shale beds are also present, but sandstone and conglomerate are the dominant lithologies (Doerner 1969).

The Jolla Vieja Formation is interpreted as representing inner and middle submarine fan deposition (Kies and Abbott 1982). Although foraminifera have not been found in the Jolla Vieja Formation, both the underlying Cañada and overlying Cozy Dell formations have foraminifera from the Narizian stage (approximately 42.5–35.3 Ma), indicating a Narizian age for the Jolla Vieja Formation as well (Doerner 1969).

Fossils found on Santa Cruz Island: The Jolla Vieja Formation is sparsely fossiliferous. Shapiro (1998) reported on a few gastropods, and Doerner (1969) noted that some localities found by Rand (1931, 1933) to have bivalves and foraminifera may be from this formation.

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Cozy Dell Shale (Middle–Upper Eocene) (Tcd)

Description: As discussed in the Santa Rosa Island section, the Cozy Dell Shale is a shale-dominated deep marine formation. On Santa Cruz Island, it is up to 279 m (915 ft) thick and composed of greenish gray to bluish gray shale and silty shale, with some arkosic sandstones and limestone nodules. Near the top of the unit is less than a meter (1–2 ft) of red shale similar to the Sespe Formation, which intervenes between the Cozy Dell Shale and Vaqueros Formation on Santa Rosa Island and the mainland. Foraminifera in the formation are assigned to the late Narizian. The upper contact with the Vaqueros Formation is disconformable (Doerner 1969).

Fossils found on Santa Cruz Island: Foraminifera have been found in abundance in the Cozy Dell Shale of Santa Cruz Island; Doerner (1969) provided lists of taxa from eight localities. A seed resembling that of *Cercidiphyllum*, bivalves, gastropods (Shapiro 1998), general bioturbation, and coccoliths (Kies 1982) have also been reported from the island. Macrofossils are rare (Shapiro 1998).

Fossils found elsewhere: The only category of fossils found in the Cozy Dell Shale of Santa Rosa Island but not Santa Cruz Island are diatoms (Weaver and Doerner 1969a). On the mainland, other fossils include leaves, plant fragments, scaphopods, crabs, lobsters, asteroids, ophiuroids, fish scales, and invertebrate burrows (Squires 1994).

Vaqueros Formation (Oligocene–Lower Miocene) (Tv)

Description: As discussed in the Santa Rosa Island section, the Vaqueros Formation is a heavily fossiliferous shallow marine formation. The Vaqueros Formation of Santa Cruz Island was included in the Temblor Formation ("Temblor Formation conglomeratic member" of Bremner 1932), and later was briefly and informally called the "Kinton Point Formation" (Bereskin 1966). It is found in southwestern Santa Cruz Island, where it can be divided into two informal members. The lower member is 169 m (555 ft) thick and conglomeratic. It is mostly made up of fragments of igneous rocks. The upper member is a brown volcanic arenite (made up of sand-sized fragments, but not necessarily a sandstone) with occasional beds of gray siltstone. It is 73 m (240 ft) thick. The upper contact with the Rincon Formation is conformable and gradational (Bereskin and Edwards 1969).

Although the Vaqueros Formation as a whole is usually regarded as marine, the conglomeratic member on Santa Cruz Island may be partially nonmarine, particularly at the base. The upper 15 m (50 ft) of this member and the volcanic arenite member above contain marine fossils. The fossils of the upper conglomeratic member suggest an inner shelf depositional setting, under subtropical waters; the fossils of the volcanic arenite member indicate inner to middle shelf deposition in the early stages, becoming entirely inner shelf higher up. The waters also warmed, supporting a tropical assemblage. Within the known outcrop belt on the island, there seems to have been a topographic high in the northeast (Bereskin and Edwards 1969).

The age of the Vaqueros Formation differs across its depositional area; on Santa Cruz Island, foraminifera are dated to the Zemorrian and early Saucesian stages (approximately 34.0 Ma to after 23.0 Ma). There may be a local depositional hiatus within the formation, based on fossil content (Bereskin and Edwards 1969).

Fossils found on Santa Cruz Island: The Vaqueros Formation of Santa Cruz Island is heavily fossiliferous (Loel and Corey 1932; Bereskin and Edwards 1969). The conglomeratic member has an invertebrate assemblage of bryozoans, bivalves, gastropods, scaphopods, barnacles, and echinoids, and vertebrate fossils including shark and ray teeth, and undescribed vertebrae. It also has reworked fossiliferous Eocene-age rock fragments (Bereskin and Edwards 1969). Howell et al. (1976) noted gastropod specimens possibly reworked from the Pozo Formation. The volcanic arenite member has yielded brachiopods, bivalves, gastropods, barnacles (Bereskin and Edwards 1969), invertebrate trace fossils including *Thalassinoides* (Shapiro 1998), and a possible whale bone (Bereskin and Edwards 1969). Mollusks are found in calcareous concretions in this member (Bereskin and Edwards 1969). Bereskin and Edwards (1969) described one foraminifera locality from the formation (member not specified).

Fossils found elsewhere: Fossil groups reported from Santa Rosa Island but not Santa Cruz Island include corals (Avila and Weaver 1969) and worm tubes (Loel and Corey 1932). There are also reworked Eocene-age coccoliths (McLean et al. 1976a). Due to the extent of the list of fossil groups found elsewhere included in the Santa Rosa Island section, its repetition here is omitted.

Rincon Formation (Lower Miocene) (Tr)

Description: As discussed in the Santa Rosa Island section, the Rincon Formation is a Miocene shaly unit deposited on the continental shelf. What is now known as the Rincon Formation on Santa Cruz Island was included as part of the Temblor Formation ("Temblor basal siltstone member" of Rand 1931, 1933; "middle shale member" of Bremner 1932) (Bereskin and Edwards 1969). This unit is found in the southwestern part of the island, where it is up to 76 m (250 ft) thick and composed of soft gray or brown calcareous shale and mudstone, with dolomitic interbeds. The upper contact with the San Onofre Breccia is gradational (Bereskin and Edwards 1969). The foraminifera found on Santa Cruz Island indicate a Saucesian age (approximately 23.0–17.5 Ma) (Bereskin and Edwards 1969).

Fossils found on Santa Cruz Island: The Rincon Formation has yielded abundant foraminifera on Santa Cruz Island; Bereskin and Edwards (1969) listed taxa from 11 localities. Ctenoid fish scales (a type of scale found on many ray-finned fish) have also been documented from the basal part of the formation (Shapiro 1998). Bremner (1932) listed bivalve and gastropod taxa from four localities in a basal sandstone layer, but other authors (Bereskin and Edwards 1969; Shapiro 1998) have not mentioned mollusk fossils, so there is a possibility that these fossils actually pertain to the underlying Vaqueros Formation, which has a gradational contact with the Rincon Formation.

Fossils found elsewhere: See the Rincon Formation section under "Santa Rosa Island Geology" for more details.

San Onofre Breccia (Lower–Middle Miocene) (Tso)

Description: The San Onofre Breccia of Santa Cruz Island is predominantly composed of conglomerate and breccia, but sandstone, siltstone, and mudstone beds are also present (Bereskin and Edwards 1969; Weaver et al. 1969b). It is found south of the Santa Cruz Island Fault (Dibblee 1982a), and is reportedly present in the subsurface north of the fault as well (Crowe et al. 1976). This formation reaches a maximum thickness of 475 m (1,560 ft) in the southwestern corner of the island (Weaver et al. 1969b). The upper contacts, with the Blanca Formation in the west and the Beechers Bay Formation in the east, are conformable and essentially arbitrary (Bereskin and Edwards 1969; Weaver et al. 1969b). On Santa Cruz Island, it was originally included in the Temblor Formation, as in Rand (1931, 1933) and Bremner (1932).

The formation's mollusks indicate shallow marine to brackish conditions, with an inner to middle continental shelf setting (Bereskin and Edwards 1969), perhaps as part of a shallow broad marine fanglomerate (alluvial fan conglomerate) in a high-energy system (Weaver et al. 1969b). It was probably deposited very near the shore, and may be partially nonmarine (Bereskin and Edwards 1969). Foraminifera in the San Onofre Breccia indicate a late Saucesian to Relizian age (between approximately 17.5 and 15.0 Ma) (Bereskin and Edwards 1969), while bivalves dated by strontium isotopes suggest a slightly older range, 19–18.2 Ma (Gordon et al. 2001).

Fossils found on Santa Cruz Island: The San Onofre Breccia of Santa Cruz Island has yielded bivalves, barnacles, and foraminifera (Bereskin and Edwards 1969; Shapiro 1998). Bereskin and Edwards (1969) listed foraminifera from four localities. Bivalves are occasionally found in growth position in the sandstone beds (Boles 1998). The formation has also yielded reworked Cretaceous or Paleocene bivalves and Paleocene gastropods (Stuart 1976).

Fossils found elsewhere: Outside of CHIS, the San Onofre Breccia has also preserved bones of pinnipeds and cetaceans (Woodford 1925).

Santa Cruz Island Volcanics (Lower–Middle Miocene) (Tsc)

Description: The Santa Cruz Island Volcanics are present north of the Santa Cruz Island Fault (Crowe et al. 1976; Gordon et al. 2001). They may be as much as 2,400 m (8,000 ft) thick (Weaver and Meyer 1969), and include sedimentary beds and numerous igneous intrusions with the volcanic flows (Nolf and Nolf 1969). Four informal members have been designated. In ascending order, from oldest to youngest, they are the Griffith Canyon Member, the Stanton Ranch Member, the Devil's Peak Member, and the Prisoners Harbor Member (Nolf and Nolf 1969; Weigand and Savage 1999). The Griffith Canyon Member may be as much as 1,100 m (3,700 ft) thick, but less than a third of this thickness can be observed in outcrop. It consists of basaltic flows and volcanic breccia. The overlying Stanton Ranch Member is 140–400 m (450–1,300 ft) thick and composed of red andesitic flows and tuff breccias. Its contact with the overlying Devil's Peak Member is disconformable in some places. The Devil's Peak Member is up to 730 m (2,400 ft) thick and composed of a variety of andesitic flows, breccias, and pyroclastics (Nolf and Nolf 1969). The contact with the overlying

Prisoners Harbor Member is disconformable (Crowe et al. 1976). Finally, the Prisoners Harbor Member is up to 180 m (600 ft) thick and composed of andesitic and dacitic flows, flow breccias, and tuff beds (Nolf and Nolf 1969). Together, they date from 17.12 to 16.1 Ma. Eruption began subaerially, but became subaqueous by the end (Weigand and Savage 1999). This is reflected in the sedimentary rocks, which include fluvial beds and beds with marine fossils (Nolf and Nolf 1969). The eruption center is thought to have been near Devil's Peak (Crowe et al. 1976; Weigand and Savage 1999). The chemical composition of the volcanics is that of an island arc (Crowe et al. 1976).

Fossils found on Santa Cruz Island: Fossils have been reported from the Prisoners Harbor Member. Foraminifera have been reported (Nolf and Nolf 1969), from a mudstone bed (McLean et al. 1976b), and cetacean bones have been found just below the contact with the Monterey Formation (Weaver and Meyer 1969) from an area mapped as the Prisoners Harbor Member.

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Beechers Bay Formation (Lower–Middle Miocene) (Tmbt)

Description: On Santa Cruz Island, the Beechers Bay Formation is exposed in a small area at Near Point, south of the Santa Cruz Island Fault. It is at least 180 m (580 ft) thick and is mostly composed of siltstone and sandstone, with some conglomerate (Bereskin and Edwards 1969). The Beechers Bay Formation of the island appears to have been deposited as turbidites in middle shelf to middle slope settings (Bereskin and Edwards 1969), and can be interpreted as an offshore facies of the Blanca Formation found on the other side of the Santa Cruz Island Fault (Weaver and Meyer 1969). Its foraminifera indicate a Relizian to Luisian age (approximately 17.5–13.6 Ma), possibly as young as Mohnian (approximately 13.6 Ma to between 8.7 and 7.4 Ma) (Bereskin and Edwards 1969). As discussed previously, this unit is also present on San Miguel Island and Santa Rosa Island.

Fossils found on Santa Cruz Island: The Beechers Bay Formation of Santa Cruz Island has yielded bivalves, barnacles, and foraminifera. The bivalves and barnacles appear to have been transported from shallower-water settings (Bereskin and Edwards 1969). Bereskin and Edwards (1969) listed taxa from five foraminifera localities (these are listed under the Monterey Formation with no member distinguished in the tables). Howell and McLean (1976) reported bathyal foraminifera from a volcaniclastic unit. The geologic map of the cited area and identification of the foraminifera as bathyal indicate the unit in question is the Beechers Bay Formation.

Fossils found elsewhere: In addition to the types of fossils known from Santa Cruz Island, the Beechers Bay Formation of San Miguel Island has also yielded brachiopods (Weaver and Doerner 1969b) and on Santa Rosa Island has also apparently yielded invertebrate burrows (Howell and McLean 1976).

Monterey Formation (shale member) (Lower–Middle Miocene) (Tmsh)

Description: As with the Beechers Bay Formation, the shale member of the Monterey Formation is also mapped on the other two large islands (see the Monterey Formation section under "San Miguel Island Geology" in particular for more details). On Santa Cruz Island, the shale member is found north of the Santa Cruz Island Fault (Bereskin and Edwards 1969). The shale member varies considerably in thickness, from approximately 490 m (1,600 ft) thick in the saddle between Cañada del Puerto and El Montañon, to a discontinuous veneer. It is a light-colored, rhythmically-bedded unit, with a propensity for landslides, and is sometimes bituminous (Weaver and Meyer 1969). The foraminifera of the member mostly date to the Luisian; in some places they may be as old as the Relizian. The foraminiferal assemblage indicates outer shelf deposition in the lower part of the member, and slope deposition later (Weaver and Meyer 1969).

<u>Fossils found on Santa Cruz Island</u>: The shale member of Santa Cruz Island has an assemblage including bivalves, gastropods, fish remains (Weaver and Meyer 1969), a desmostylian (Barnes and Aranda-Manteca 1997; Domning and Barnes 2007), whale bones, foraminifera, and diatoms (Weaver and Meyer 1969). Foraminifera are most common in the lower part of the member. The most abundant macrofossils are the bivalve *Pecten peckhami* and fish scales and bones (Weaver and Meyer 1969). Weaver and Meyer (1969) listed taxa from six foraminifera localities. Hornafius and Lagle (1984) noted the presence of diatoms. The undescribed desmostylian is represented by a partial skull and vertebrae found in the Monterey Formation (Figure 17) (Barnes and Aranda-Manteca 1997; Domning and Barnes 2007); information with the specimen shows it was collected in 1965 from the shale member. Aranda-Manteca and Barnes (1998), in a conference abstract, proposed naming this specimen "*Jamilcotatus boreios*" but a formal publication has not been issued.

Figure 17. Part of the desmostylian specimen from Santa Cruz Island in LACM collections; locality information has been redacted from the specimen card (NPS/JUSTIN TWEET).

<u>Fossils found elsewhere</u>: Santa Cruz Island has the most diverse fossil record for the shale member of any of the CHIS islands, and no group is found on any other island that is not represented here.

Blanca Formation (Middle Miocene) (Tb)

Description: The Blanca Formation is a volcaniclastic unit found south of the Santa Cruz Island Fault (Fisher and Charlton 1976). It has occasionally been extended to San Miguel Island (McLean et al. 1976a; Dibblee 1982a) and Santa Rosa Island (Howell and McLean 1976; McLean et al. 1976a; Dibblee 1982a; McLean and Howell 1984; Savage et al. 1991), by incorporating some or all of the Beechers Bay Formation interval. Santa Rosa Island in particular may have rocks from the same volcanic complex and submarine fan as the Blanca Formation of Santa Cruz Island (Howell and McLean 1976; Savage and Weigand 1994).

The Blanca Formation can be divided into lower, middle, and upper members. The lower member is composed of conglomerate and sandstone, and is similar to the underlying San Onofre Breccia. The middle member is generally the thickest, and consists of tuff, tuff breccia, volcaniclastic conglomerate, and sandstone. The upper member is composed of tuff breccia and sandstone, conglomerate, and breccia (Weaver et al. 1969b; Fisher and Charlton 1976). The upper member also includes an andesitic flow (Weaver et al. 1969b). The lower and middle members have a conformable contact, while the middle and upper members have a mostly conformable contact (Fisher and Charlton 1976). The most complete section is 436 m (1,430 ft) thick (Weaver et al. 1969b). The formation is noted for being resistant to erosion (Weaver et al. 1969b). Most of CHIS's sea caves are in the Blanca Formation (Santucci et al. 2001).

The relationship of the Blanca Formation with the Santa Cruz Island Volcanics is unclear, although it is known that the two formations did not have the same source (Fisher and Charlton 1976; McLean et al. 1976b; contra Weaver and Meyer 1969). The Beechers Bay Formation is thought to be a lateral equivalent of the Blanca Formation (Bereskin and Edwards 1969; Fisher and Charlton 1976). The Blanca and Monterey formations may interfinger in places (McLean et al. 1976a).

The Blanca Formation was deposited in a nearshore marine setting near an active volcanic source (Weigand and Savage 1999), which may have been located between Santa Cruz and Santa Rosa islands (McLean et al. 1976a). Part of the formation may have been deposited in a nonmarine alluvial fan (McLean and Howell 1984). Sediment burial was rapid (Fisher and Charlton 1976). Volcanic rock fragments in the formation date from 14.9 to 13.3 Ma (Weigand and Savage 1999), and the volcanic flow in the upper member dates to 14.5 ± 0.8 Ma (McLean et al. 1976a).

Fossils found on Santa Cruz Island: It is not clear if the Blanca Formation is fossiliferous on Santa Cruz Island. Bivalves and barnacles cited by Fisher and Charlton (1976) are the same as fossils cited for the San Onofre Breccia by Weaver et al. (1969b). Similarly, foraminifera from a volcaniclastic unit mentioned by Howell and McLean (1976) are in an area mapped as the Beechers Bay Formation. Fisher and Charlton (1976) and McLean et al. (1976b) reported the presence of fossil fragments in the basal lower member, but it is not clear whether or not these records pertain to the Blanca Formation or the San Onofre Breccia. Fisher and Charlton (1976) did not report fossils higher than the basal lower member.

Fossils found elsewhere: This unit is (currently) limited to Santa Cruz Island.

Potato Harbor Formation (Pleistocene) (Qph)

Description: The Potato Harbor Formation is mostly composed of sandy limestone and is as much as 26 m (85 ft) thick, but is usually less than 6 m (20 ft) thick. It is an eolian formation, deposited in very shallow marine and beach settings (Weaver and Meyer 1969). It includes basal fossiliferous marine terrace sediments overlain by eolian deposits (Muhs et al. 2018). It is mapped in northeastern Santa Cruz Island (Weaver and Nolf 1969). This formation is found only on Santa Cruz Island, although there are similar (albeit possibly younger) rocks on San Miguel Island (Weaver and Meyer 1969). The Potato Harbor rocks were previously known under other names, such as the Santa Barbara Formation (Rand 1931, 1933) and the San Pedro Formation (Bremner 1932). The age of the formation is uncertain, and has been suggested to be as old as the Pliocene based on the presence of the bivalve *Pecten healeyi* (now *Patinopecten healeyi*; Weaver and Meyer 1969). Muhs et al. (2018) suggested it was at least on the order of 900,000–1,000,000 years old.

Fossils found on Santa Cruz Island: The Potato Harbor Formation has yielded root casts, bryozoans, bivalves, gastropods, barnacles, echinoids, and foraminifera. It also has rocks that may have been derived from algal activity, and many of its constituent grains are actually sand-sized fragments of algae, bryozoans, mollusks, echinoids, and foraminifera. Most of these fossils come from the base of the unit; terrestrial gastropods and the root casts were found elsewhere in the formation (Weaver and Meyer 1969). The root casts are found in the upper eolian part of the formation (D. Muhs, pers. comm., April 2020). Weaver and Meyer (1969) reported six macrofossil localities in this formation.

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Middle Anchorage Alluvium (Pleistocene) (Qma)

Description: The Middle Anchorage Alluvium is a red and brown sandy pebble- to cobble conglomerate covering about 65 ha (160 acres) of the Middle Anchorage area. It is interpreted as representing beach deposition and terrestrial alluvium (Weaver and Meyer 1969).

Fossils found on Santa Cruz Island: The only fossils reported from this unit are pholad bivalve borings in some reworked clasts of Monterey Formation shale (Weaver and Meyer 1969).

Fossils found elsewhere: This unit is limited to Santa Cruz Island.

Quaternary rocks and sediments (Pleistocene–Holocene)

Description: Santa Cruz Island has similar Quaternary deposits to the other islands of CHIS, featuring a combination of eolian, alluvial, landslide, and marine terrace deposits. The relatively young Quaternary sediments of the island have occasionally been called the Santa Cruz Island Formation (Chaney and Mason 1930; Fergusson and Libby 1963). Marine terraces are best developed in the western part of the island, where three have been distinguished (Pinter et al. 1998; Muhs and Groves 2018).

Fossils found on Santa Cruz Island: The paleontology of the late Quaternary on Santa Cruz Island is relatively unknown compared to San Miguel and Santa Rosa Islands, but what has been published is similar, and more exploration and description will probably reinforce that similarity. All three were part of Santarosae and would have shared a common flora and fauna as recently as a few thousand years ago.

While San Miguel Island is noted for its diverse Quaternary avifauna and Santa Rosa Island is known for pygmy mammoth fossils, Santa Cruz Island's best-known Quaternary fossils are plant fossils (Figure 18). First described by Chaney and Mason (1930), the Pleistocene floral assemblage of the island includes: three species of mosses (Grant 2016); the trees *Cupressus goveniana* (cypress), *Myrica californica* (California bayberry), *Pinus radiata* (Monterey pine), *Pinus remorata* (island bishop pine, sometimes synonymized with *P. muricata*), and *Pseudotsuga menziesii* (Douglas-fir); the shrubs *Arctostaphylos* sp. (manzanita), *Ceanothus thyrsiflorus* (blueblossom), *Cornus californica* (dogwood), and *Garrya elliptica* (coast silk-tassel), and the herb *Arceuthobium campylopodum* (western dwarf mistletoe) (Chaney and Mason 1930; Johnson 1977; Grant 2016). These taxa are represented by material including seeds, cones, needles, leaf fragments, stem fragments, wood, and logs (Chaney and Mason 1930; Grant 2016). Four types of seeds from unknown plants have also been found (Chaney and Mason 1930), as well as other fragmentary material (Grant 2016). This material came from a clay, sand, and gravel deposit up to 9–11 m (30–35 ft) thick in the southwestern part of the island (Chaney and Mason 1930), discovered by R. C. Olson in 1927 (Cushing et al. 1984). Descriptions of pollen and charcoal records from this and other sites on Santa Cruz Island are underway (R. S. Anderson, pers. comm., April 2020). Late Holocene pollen and charcoal records are included in Anderson (1998), and some charcoal dates can be found in Pinter et al. (2011).

Twenty-three logs with diameters greater than 20 cm (8 inches) were reported by Chaney and Mason (1930). Anderson et al. (2008) reported that they have now eroded to small fragments, but R. Scott Anderson (not the same person) stated that they are still present, but the observer has to know where to look for them (pers. comm., April 2020). Several Douglas-fir specimens from the assemblage have been dated between 14,200 ± 250 radiocarbon yr BP (17,910–16,530 cal yr BP) (Fergusson and Libby 1963) and 11,760 ± 100 radiocarbon yr BP (13,780–13,400 cal yr BP) (Pinter et al. 1998), with a range of dates between these endpoints in Anderson et al. (2008), and charcoal has been dated to 33,400 ± 420 radiocarbon yr BP (38,630–36,480 cal yr BP) (Pinter et al. 1998). R. Scott Anderson has additional unpublished dates on Douglas-fir within this time range, as well as an unpublished pollen assemblage (pers. comm., April 2020). The paleofloral assemblage suggests a woodland of trees and shrubs (Mead et al. 2004), comparable to the modern-day vegetation around Fort Bragg, 685 km (425 mi) to the north-northwest (Chaney and Mason 1930). The presence of Douglas-fir is of interest, because Santa Cruz Island is 100 km (60 mi) south of their present range. Isotopes from island specimens indicate that these trees were acquiring moisture from fog. They died out after approximately 15,000 cal yr BP, possibly from a combination of increased summer heat and insufficient precipitation (Anderson et al. 2008). Other publications that discuss the Pleistocene flora of Santa Cruz Island include Stock (1935), Cockerell (1938b), Axelrod (1983, 1986), Santucci et al. (2001), and Grant (2016), who also identified insect and millipede fragments from the site. Higher in section (extrapolated ages of 7650–5000 radiocarbon years before present), aquatic and terrestrial snails and freshwater ostracodes have also been found here (Snyder 2000).

Figure 18. A fossil log (*Pseudotsuga menziesii*, Douglas-fir [R. S. Anderson, pers. comm., April 2020]) on Santa Cruz Island, photographed in 1979. Photo by Steve Junak, courtesy of the Santa Barbara Botanic Garden.

The late Quaternary invertebrates and vertebrates are known from a few reports. Published reports of invertebrates include a middle Holocene shell, a coral (*Balanophyllia elegans*) from the 125 ka (thousand years) terrace (Pinter et al. 1998), a handful of marine Pleistocene bivalve and gastropod taxa (Muhs and Groves 2018), and the gastropods and arthropods mentioned above (Snyder 2000; Grant 2016). Published vertebrates include Pleistocene remains of mammoths (see below) and Holocene island foxes (sometimes found in burial contexts; Collins 1991) and dogs (Rick et al. 2008). A more diverse unpublished Pleistocene fauna is present in the collections of the San Diego Natural History Museum collections. Many of the fossils represent groups not otherwise reported: encrusting bryozoans, several taxa of chitons, barnacles, crabs, echinoids, birds, pinnipeds, cetaceans, invertebrate trace fossils, and foraminifera. These collections also greatly increase the number of bivalve and gastropod species.

The only Pleistocene vertebrates reported in the formal literature from Santa Cruz Island are mammoths, although Snyder (2000) mentioned but did not describe small vertebrate bones in sediment of early to middle Holocene age, illustrating the potential for other finds. Mammoth fossils were discovered on the island in the late 1920s. D. B. Rogers, an archeologist from the Santa Barbara Museum of Natural History, found two teeth in an Indian burial, and R. C. Olson, an anthropologist from UC-Berkeley, found two tooth plates in the same time frame (Cushing et al. 1984) (Figure 19).

Olson's find was mentioned in print by Chaney and Mason (1930), and Stock (1935) suggested that the tooth plates had been brought to Santa Cruz Island by the early human inhabitants. This idea has since been challenged (Cushing et al. 1984). By 1984, seven mammoth specimens had been found on the island. These finds consisted of six teeth and a partial femur (Cushing et al. 1984). A tusk was documented later (Wenner et al. 1991) (Figure 20 may represent this specimen). The early Santa Cruz Island specimens were not regarded as obviously dwarfed (Roth 1996a), although at least one specimen has since been attributed to *M. exilis* (Semprebon et al. 2016). Other publications that mention Santa Cruz Island mammoth remains include Johnson (1978), Agenbroad (1998, 1999b), Agenbroad et al. (2005), Muhs et al. (2015), and Pigati et al. (2017).

<u>Fossils found elsewhere</u>: Given the high likelihood that Santa Cruz Island had essentially the same flora and fauna as San Miguel Island and Santa Rosa Island during Santarosae time, the fossils found on those two islands can be used as guides for what may exist undiscovered on Santa Cruz Island. Unpublished material, including palynomorphs under description by R. Scott Anderson (pers. comm., April 2020), greatly increases the Quaternary record of the island.

Figure 19. One of Olson's mammoth tooth plate specimens, in LACM collections (NPS/JUSTIN TWEET).

Figure 20. A mammoth tusk in situ, observed in 1984. Photo by Steve Junak, courtesy of the Santa Barbara Botanic Garden.

Anacapa Island Geology

Anacapa Island is treated as one island or several islets by different sources. It is an elongate and slightly sinuous landmass about 10 km (6 mi) long, and under most sea-level conditions is divided into three main islets (West Anacapa Island, Middle or more rarely Central Anacapa Island, and East Anacapa Island). Few pre-Quaternary geological units are differentiated on the island, which is composed of Miocene volcanic rocks with lesser quantities of interbedded sedimentary rocks, sculpted by more recent erosion and overlain extensively by Quaternary deposits, particularly fossiliferous Pleistocene marine terrace deposits. Geologic units exposed on Anacapa Island include, from oldest to youngest, Early–Middle Miocene-age volcanics and associated sedimentary rocks, the interbedded San Onofre Breccia, and Quaternary rocks and sediments (Norris 1995; Schmidt et al. in prep. a) (Figure 21, Table 4).

The source maps for the geologic maps prepared for Anacapa Island and Santa Barbara Island (see that section as well) differ from the maps prepared for the three larger islands in that they are focused on surficial deposits, dividing these very finely. However, this inventory discusses Quaternary deposits collectively. One result of this is that the ages of the various Quaternary deposits mapped on Anacapa and Santa Barbara islands are not discussed in the text, so they are included in the legends of the maps for reference. Ages are not included in the map legends for the three larger islands because they are discussed frequently throughout the text, and their absence leaves more space for other elements of the maps.

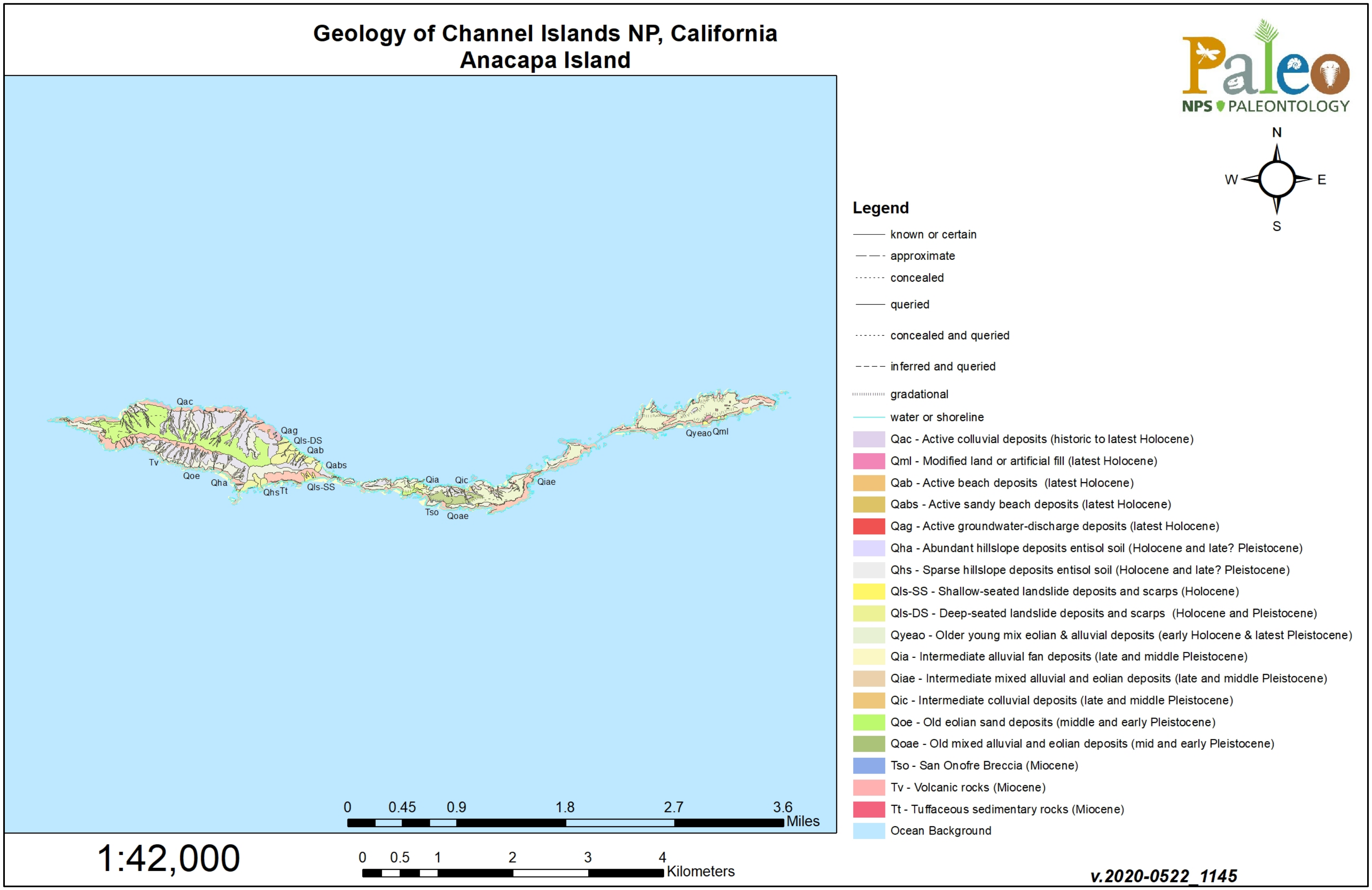

Figure 21. Geological map of Anacapa Island derived from Schmidt et al. (in prep. a), digitized by the NPS GRI. Digital map data is available at https://irma.nps.gov/DataStore/Reference/Profile/2244208. The only definitely unfossiliferous unit is Tv (Miocene volcanics), which incorporates potentially fossiliferous rocks.

Table 4. Summary of Anacapa Island stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. Details and references can be found in the text and in Tweet et al. (2012).

Formation	Age	Fossils Found on Anacapa Island	Depositional Environment
Quaternary rocks and sediments	Pleistocene–Holocene	Pleistocene: bryozoans, chitons, bivalves, gastropods, scaphopods, worm tubes, barnacles, crabs, ostracodes, a beetle (possibly modern contaminant), echinoids, undetermined shells, California sheephead, several bird taxa (primarily marine birds), extinct deer mice, undetermined vertebrate remains (fishes, birds, mammals), sponge borings on shells, tube worm trace fossils, and foraminifera	Shallow marine to terrestrial settings
Anacapa Island volcanics and associated sedimentary rocks	Early–Middle Miocene	Marine gastropods	Submarine to subaerial volcanic flows

Geologic Formations

Anacapa Island volcanics and associated sedimentary rocks (Lower–Middle Miocene) (Tt, Tv, Tso)

Description: Lower–Middle Miocene volcanics make up most of the bedrock of Anacapa Island (Norris 1995). These rocks are sometimes identified as the Conejo Volcanics, a unit known from the mainland (Scholl 1959, 1960; Dibblee 1982a; Norris 1995). The volcanics are andesitic in composition, similar to the Santa Cruz Island volcanics (Weigand and Savage 1999), and are approximately 520 m (1,700 ft) thick (Scholl 1960). Beds of San Onofre Breccia are interbedded with the volcanics (Lipps 1964; Norris 1995; Weigand and Savage 1999), with two intervals of breccia 11–12 m (35–40 ft) thick separated by 30–46 m (100–150 ft) of volcanics (Scholl 1960). These breccia beds are found in the lower 61–91 m (200–300 ft) of the exposed volcanic series (Scholl 1960). The breccia is dominated by fragments of metamorphic rocks, particularly schist. Pink or light green silty sandstone is also intercalated with the breccia, made of smaller fragments of the same kinds of rocks (Scholl 1959). Outcrops of the San Onofre Breccia can be found on the north and south sides of the east end of the middle island and the south side of the east end of the western island (Norris 1995). Inclusions of shale are common in the extrusive rocks beneath the breccias, and may have been plucked up during subaqueous eruptions. Marine siltstones have been found beneath the andesitic flows on the central island (Scholl 1959). The Anacapa Island volcanics are at least partially submarine in origin (Norris 1995), although the associated breccias and sandstones seem to be mostly alluvial (Scholl 1959). The volcanics date to between 16.28 and 15.8 Ma (Weigand and Savage 1999).

Fossils found on Anacapa Island: Poorly preserved marine gastropods have been found in the marine siltstone (Scholl 1959). From the description of the rocks, they seem to be examples of the unnamed sedimentary rocks associated with the volcanics, not the San Onofre Breccia.

Fossils found elsewhere: This collective unit is limited to Anacapa Island.

Quaternary rocks and sediments (Pleistocene–Holocene)

Description: The Quaternary deposits of Anacapa Island include older, early Pleistocene deposits, and younger late Pleistocene deposits. There are several marine terraces on the island. The highest confirmed terrace, at approximately 180 m (600 ft), is found only on the north and west sides of West Anacapa Island (Scholl 1960). Johnson (1979) reported that unfossiliferous marine deposits were present even higher, at the highest elevations of West Anacapa Island, but these were not confirmed by Muhs and Groves (2018). Fossiliferous terraces are present at approximately 76 m (250 ft) and 11 m (36 ft) (Muhs and Groves 2018). Interestingly, the marine terraces are overlain by terrestrial colluvium; there is no extant source for the colluvium, which therefore seems to have derived from now-eroded land on the south side of the island (Muhs and Groves 2018).

The lower terrace dates to the last interglacial period, possibly including fossils from approximately 100 and 120 ka (Muhs and Groves 2018), and the higher terrace dates to approximately 1.7–1.6 Ma (D. Muhs, pers. comm., February 2012). These terraces and those in the immediate offshore area illustrate both changes in sea level and the influence of tectonics (Norris 1995). On the central island, the 76-m terrace includes less than 1 m (<3 ft) of fossiliferous marine sand unconformably overlying the San Onofre Breccia. An area at the north edge of the terrace near the eastern end of the central island is further overlain by 8–9 m (25–30 ft) of alluvial sand deposited during the late Pleistocene, eroded from a now-lost higher outcrop of San Onofre Breccia (Scholl 1960). On the western island, the 11-m terrace is covered by fossiliferous marine and nonmarine deposits. They include, in ascending order, a lower marine sandy conglomerate, talus, supralittoral beach sand, and another talus deposit (Lipps 1964). Because the marine fossils from the 11-m terrace include both warm and cool faunal elements, the overall assemblage is thought to record a mix of warm period material from approximately 120 ka reworked into cool period deposits from a marine high stand at approximately 100 ka (Muhs and Groves 2018).

Fossils found on Anacapa Island: Most of the Pleistocene fossils reported from Anacapa Island came from the 76-m terrace deposits on the central island or the 11-m terrace deposits on the western island, and are primarily marine in origin. The setting for the marine faunas is interpreted as rocky and intertidal (Muhs and Groves 2018). On the central island, Scholl (1960) first reported mollusks and foraminifera. Valentine and Lipps (1963) provided a more thorough description of the assemblage, which yielded approximately 120 species of chitons, bivalves, gastropods, scaphopods, barnacles, and echinoids, and rare fish and bird bones. These collections are now at the LACM. Later, Kern et al. (1974) reported polychaete worm tubes in gastropod shells from the UCLA specimens.

Collectors from the LACM are responsible for the described collections from the western island (Lipps 1964). Marine fossils from the marine conglomerate at the base of the lower deposits included 12 species of chitons, bivalves, and gastropods, and fragments of echinoids. These fossils were generally incomplete. The coastal sediments above included fossils of terrestrial gastropods; barnacles; a beetle (possibly a modern contaminant); sheephead fish; bones of 10 species of birds, predominantly the flightless duck *Chendytes lawi* (Figures 22 and 23) (also present were alcids, auklets, murrelets, condors, gulls, petrels, cormorants, and shearwaters); the deer mouse *Peromyscus*; and an indeterminate vertebrate (Lipps 1964). Muhs and Groves (2018) re-evaluated the invertebrate specimens from the 11-m terrace and published a list with numerous additional species, representing chitons, bivalves, gastropods, worm tubes, barnacles, crabs, echinoids, and indeterminate fishes and birds. The extinct “giant” deer mouse species *Peromyscus anyapahensis* was named from a specimen found at West Anacapa Island (holotype LACM 9205) (White 1966). Miller et al. (1961) and Howard (1964a) also reported fossils from the LACM sites. The NPS constructed a building in the area of these localities, which was removed in 1985; Guthrie (1998) reported that almost nothing of the fossiliferous sediments remained. There is some ambiguity about what was lost, because Guthrie’s description implied that there was only one fossiliferous locality, but Lipps (1964) referred to several localities over an area.

Figure 22. A skull of *Chendytes* from Anacapa Island in LACM collections (NPS/JUSTIN TWEET).

Figure 23. A *Chendytes* sacrum and pelvis from Anacapa Island in LACM collections (NPS/JUSTIN TWEET).

The San Diego Natural History Museum includes collections from Anacapa Island that largely replicate the LACM collections, but also include bryozoans, ostracodes, and sponge borings on shells, which have not been reported from the LACM collections. Finally, potential Holocene- or latest-Pleistocene-age material in a cultural context was mentioned by Yates (1890a), who observed marine shells and fish and cetacean bones in a cave with a spring, but without age control or a more thorough description this report is mostly a curio.

It is worth noting that there is a curious report of fossiliferous asphalt found on Anacapa Island in conjunction with the grounding of the oil tanker *Liebre* in 1921. As reported by the Los Angeles Times on March 2, 1921, the tanker went aground late on February 28, 1921. Although the newspaper report indicated that the vessel was able to pull out without discharging any of its cargo of oil, this is contradicted by the report of casualty, which stated that the forward deep tanks were emptied (Morris and Lima 1996). On March 11, 1921, the Morning Times (Santa Barbara) ran the following item:

> *"Ship's Bow Plows Up Fossil Remains On Anacapa Island—The stranding of the oil tanker Liebre on Anacapa Island during a dense fog recently has proved an event of scientific significance. When the bow of the vessel drove into the beach, it uncovered an asphaltum deposit in which were found a number of bones. These according to advices from Ventura, have been identified by scientists of the University of California as the fossil remains of mastodons and sabre-tooth tigers. The theory is held that the asphaltum deposit was once in a more liquid state and acted as a trap for the prehistoric monsters as did the asphaltum pools at La Brea. The asphaltum has kept the bones in an excellent state of preservation, and they will be sent to the Smithsonian Institute at Washington."*

Nothing of this find has ever been reported elsewhere. Assuming that the news item is not fanciful, an alternative explanation is that the beach around the site was fouled with oil dumped from the *Liebre*, which was misinterpreted by an observer who wasn't aware that oil had been released. The bones may have been modern marine mammal bones.

<u>Fossils found elsewhere</u>: The specific deposits are limited to Anacapa Island, but the Quaternary marine and terrestrial deposits of the other CHIS islands have similar fossil assemblages, albeit with more diverse terrestrial fossils. Notably, Anacapa Island is the only part of Santarosae where mammoth fossils have not been found, but it is not out of the question that such fossils will eventually be found there.

Santa Barbara Island Geology

Like Anacapa Island, Santa Barbara Island is composed of Miocene volcanics largely concealed by Quaternary surficial deposits. Despite the basic similarity, Santa Barbara Island has a separate geological history and origin, not being part of the Transverse Ranges. It is relatively understudied compared to the three large islands. Units exposed on Santa Barbara Island include Early–Middle Miocene-age volcanics and associated sedimentary rocks, and Quaternary rocks and sediments (Vedder and Howell 1976; Norris 1991; Weigand and Savage 1999; Muhs and Groves 2018; Schmidt et al. in prep. b) (Figure 24, Table 5). Most but not all of these units are fossiliferous.

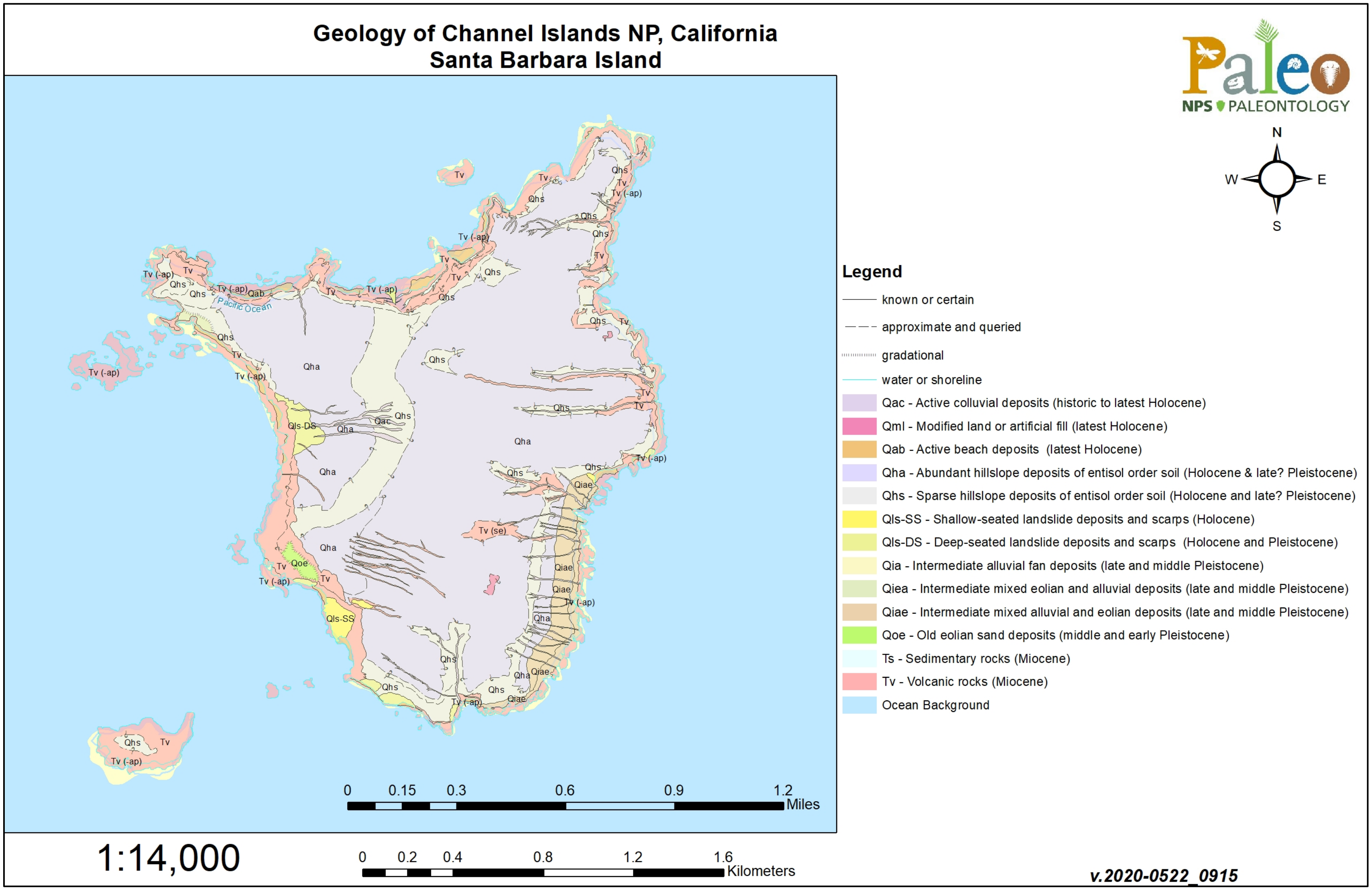

Figure 24. Geological map of Santa Barbara Island derived from Schmidt et al. (in prep. b), digitized by the NPS GRI. Digital map data is available at https://irma.nps.gov/DataStore/Reference/Profile/2244209.

Table 5. Summary of Santa Barbara Island stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. Details and references can be found in the text and in Tweet et al. (2012).

Formation	Age	Fossils Found on Santa Barbara Island	Depositional Environment
Quaternary rocks and sediments	Pleistocene–Holocene	Pleistocene: corals, chitons, bivalves, gastropods, possible worm tubes, barnacles, crabs, ostracodes, echinoids, undetermined invertebrates, fish bones, isolated bones of birds and sea lion, and foraminifera late Holocene: flowering plants, chitons, cephalopods, terrestrial snails, crabs, insects, echinoids, ray-finned fish, lizards, diverse birds, deer mice, bird eggshells, and owl pellets	Shallow marine
Santa Barbara Island volcanics and associated sedimentary rocks	Early–Middle Miocene	Foraminifera	Volcanic flows at upper bathyal depths

Geologic Formations

Santa Barbara Island volcanics and associated sedimentary rocks (Lower–Middle Miocene) (Ts, Tv)

Description: Santa Barbara Island's bedrock is mostly composed of volcanics, with some intercalated marine sedimentary rocks (Vedder and Howell 1976; Weigand and Savage 1999). The sequence includes a lower section of andesitic to basaltic flows, a middle section of volcanic flows, siltstone, claystone, and shale, and an upper section of volcanic breccia. The lower section is seen in the western half of the island, and the upper section is seen in the northeast. Although volcanic rocks are common here, the actual vent was probably elsewhere (Vedder and Howell 1976). All three divisions appear to have been deposited or erupted in a marine setting (Norris 1991). The volcanics range in age from 16.8 to 14.8 Ma (Weigand and Savage 1999).

Fossils found on Santa Barbara Island: Foraminifera have been found in the claystone and shale of the middle interval. They indicate deposition at upper bathyal depths and are considered to be Luisian in age (Vedder and Howell 1976). They were first reported by Kemnitzer (1933), who found them in a "fine grained sandy shale composed chiefly of foraminifera". This bed is cm-scale to m-scale in thickness (several inches to several feet) and is exposed on cliff faces on the north and south sides of the island.

Fossils found elsewhere: This collective unit is limited to Santa Barbara Island.

Quaternary rocks and sediments (Pleistocene–Holocene)

Description: Surficial deposits on Santa Barbara Island include marine terrace deposits, eolian deposits, and alluvial deposits (Schmidt et al. in prep. b). Quaternary deposits range from a few cm (a few in) to approximately 12 m (40 ft) thick, and are thickest in the northwest part of the island (Kemnitzer 1933). The island has at least four marine terraces, perhaps five. The shoreline angle elevations of these terraces are 11 m (36 ft), 30–33 m (98–110 ft), 44–51 m (140–170 ft), 66–82 m (220–270 ft), and possibly between 100 and 120 m (330 and 390 ft). Fossiliferous deposits are present on the four confirmed terraces (Muhs and Groves 2018). As on Anacapa Island, marine fossils from the 11-m terrace include both warm and cool faunal elements, suggesting a mix of 120 ka and 100 ka material, and the setting for the marine assemblages is interpreted as rocky intertidal (Muhs and Groves 2018).

Fossils found on Santa Barbara Island: Kemnitzer (1933) briefly reported observing indeterminate foraminifera, shell fragments, and specimens of the gastropod *Haliotis* from the Quaternary sediments. Lipps et al. (1968) described fossils from terraces measured at 9–10 m (25–30 ft) and 40 m (130 ft). The assemblages represent two different marine highstands, but both were from an open coastal setting under 3–6 m (10–20 ft) of water. The fossil assemblage of the lower terrace as reported by Lipps et al. (1968) included stony corals, bivalves, gastropods, ostracodes, a single bone each of a bald eagle and a sea lion, and foraminifera. The fossil assemblage of the higher terrace was limited to bivalves, gastropods, ostracodes, and foraminifera. Like the Pleistocene fossils of Anacapa Island, these fossils were collected by the LACM (Lipps et al. 1968). Other documents which mention these fossils include Valentine and Lipps (1966), Delaca and Lipps (1972), Roth (1996b), and Santucci et al. (2001). The sandy alluvium of the island locally preserves abundant fossils of terrestrial snails (Roth 1996b). Among them is a taxon described in Pilsbry (1939) as *Micrarionta facta* form *intermedia*, now regarded as its own fossil species, *M. intermedia* (Pearce 1990; Roth 1996b). A Pleistocene alcid humerus was later collected from the island for the LACM (Figure 25).

Figure 25. A humerus of the extinct alcid *Mancalla* cf. *californiensis* from Santa Barbara Island in LACM collections (NPS/JUSTIN TWEET).

Muhs and Groves (2018) reassessed the LACM collections, placing the LACMIP localities on the various terraces. They also re-identified the taxa from the first terrace, expanded to include chitons, possible worm tubes, barnacles, crabs, echinoids, and fish bones.

Although the material is younger than what is usually considered fossil, a significant cave fauna representing an owl roost should also be mentioned. To date, material described from the cave only goes back approximately 1,500 years, but the cave deposits are reported to encompass several thousand years (Collins et al. 2018b). Organisms documented for the past 1,500 years of deposits, an important time frame for changes in the island's ecosystem, include: flowering plants; chitons; squids; terrestrial snails; insects; echinoids; fishes; island night lizards (*Xantusia riversiana*); deer mice; and diverse birds (Collins et al. 2018b).

Fossils found elsewhere: The specific deposits are limited to Santa Barbara Island, but the Quaternary marine and terrestrial deposits of the other CHIS islands have similar fossil assemblages, albeit with more diverse terrestrial fossils.

Taxonomy

See Appendix A for full lists of taxa.

Fossil Plants

CHIS is not noted for having a diverse or lengthy record of fossil plants, but all of the islands except Anacapa Island have some sort of pre-historical plant material, and calichified "forests" are one of the most noted types of paleontological resources on the islands, particularly on San Miguel Island. The three largest islands also have Quaternary pollen records, and a small assemblage of Pleistocene plant macrofossils and megafossils is known from Santa Cruz Island. In addition, there are several described and undescribed Quaternary palynomorph records from the three large islands.

Although caliche deposits are also well-developed on Santa Rosa Island, San Clemente Island, and San Nicolas Island, San Miguel Island is particularly noted for these deposits (Figure 26) (Johnson 1967). Carbonate-rich sands are transported from the insular shelf and deposited as dunes. Vegetation stabilizes the dunes and soils begin to form in the upper part. Carbonate rhizoliths form as both root sheaths and root casts when the carbonate sand grains are dissolved and re-precipitated. Laminar caliche (calcrete) forms above this within the soil zone; this type of caliche is not a fossil of a plant but a soil horizon. Carbonates have formed around plant structures, leaving hollows, or filled in casts of roots, stems, and trunks. One log on San Miguel Island has a diameter of 0.76 m (2.5 ft) and is 9 m (30 ft) long (Johnson 1967). The identity of these rhizoliths as plant fossils has been recognized since the 1890s (Voy 1890–1893b). Voy (1890–1893b) and Cockerell (1938b) interpreted the concretions as having formed around roots of *Rhus integrifolia* (lemonade sumac), and Johnson (1977) used them to infer the presence of shrub vegetation during the latest Pleistocene. Within CHIS, aside from San Miguel and Santa Rosa islands, calichified plant structures are also known from the upper eolian Potato Harbor Formation on Santa Cruz Island (Weaver and Meyer 1969). Calichification is not the only mode of preservation possible on the islands. More conventional petrified wood has been observed on Santa Rosa Island (Figure 37), where such fossils are probably more abundant than would be known from the literature, and Johnson (1967) reported pink and white opalized stem and trunk casts on Santa Cruz Island.

In addition to the caliche forests and other mineralized specimens, a small number of plant taxa have been identified from the late Quaternary deposits of San Miguel Island, including conifers and angiosperms (Johnson 1977; West and Erlandson 1994, which reported palynomorphs), among them the tree *Pinus* (pines) and the shrubs *Rhus* (sumacs) and *Ribes* (currants) (Johnson 1977). R. Scott Anderson (pers. comm., April 2020) has a small unpublished pollen record from near the landing strip of late Holocene age. Charcoalified wood of angiosperms (*Ceanothus*, lilacs) and conifers (*Abies*, firs) was mentioned by Rick et al. (2012a) from Santa Rosa Island, and R. Scott Anderson (pers. comm., April 2020) has observed wood of *Pinus* and *Prunus* (cherries) in northwestern Santa Rosa Island.

Figure 26. An example of a calichified “fossil forest” on San Miguel Island (NPS).

Figure 27. A large piece of petrified wood on Santa Rosa Island (NPS/JUSTIN TWEET).

Santa Cruz Island's best-known Quaternary fossils are plant fossils. The Pleistocene floral assemblage of the island includes several identifiable taxa plus four types of unidentified seeds: mosses (Grant 2016); the trees *Cupressus goveniana* (cypress), *Myrica californica* (California bayberry), *Pinus radiata* (Monterey pine), *Pinus remorata* (island bishop pine, sometimes synonymized with *P. muricata*), and *Pseudotsuga menziesii* (Douglas-fir); the shrubs *Arctostaphylos* sp. (manzanita), *Ceanothus thyrsiflorus* (blueblossom), *Cornus californica* (dogwood), and *Garrya elliptica* (coast silk-tassel), and the herb *Arceuthobium campylopodum* (western dwarf mistletoe) (Chaney and Mason 1930; Johnson 1977; Grant 2016). Fossils include material ranging from seeds and cones (Figure 28) to wood and logs (Chaney and Mason 1930).

Figure 28. Pleistocene conifer cones found on Santa Cruz Island, 1982. Photo by Steve Junak, courtesy of the Santa Barbara Botanic Garden.

Palynomorphs, organic microfossils such as pollen and spores, are important for paleoecological studies because they illustrate the flora of a location. Palynological studies have been performed on San Miguel Island and Santa Rosa Island. On San Miguel Island, pollen indicates the presence of a pine forest for at least the northeast coast of the island near the end of the Pleistocene, transitioning into a coastal shrub assemblage near the Pleistocene–Holocene boundary (West and Erlandson 1994; Erlandson et al. 1996). On Santa Rosa Island, Quaternary palynomorphs have been by Cole and Liu (1994) and Anderson et al. (2010). The palynomorphs show that the island had a coastal conifer forest near the end of the Pleistocene, replaced at approximately 11,800 cal yr BP by grassland and scrub as the climate became warmer and drier (Anderson et al. 2010). Descriptions of additional palynomorph and charcoal records for Santa Cruz and Santa Rosa islands are underway (R. S. Anderson, pers. comm., April 2020).

Only a few plant fossils have been reported outside of the young Quaternary deposits. From Santa Cruz Island, there are wood casts in the Cañada Formation (Shapiro 1998), a seed resembling that of *Cercidiphyllum* in the Cozy Dell Shale (Shapiro 1998), and root casts in the Potato Harbor Formation (Weaver and Meyer 1969). From Santa Rosa Island, carbonaceous fragments have been reported from the Rincon Formation (Avila and Weaver 1969).

Fossil Invertebrates

Abundant marine invertebrate assemblages have been reported from all five CHIS islands. These assemblages are dominated by bivalve and gastropod mollusks, followed by barnacles and echinoids, and then a host of other groups (various less abundant classes of mollusks and arthropods, sponges, corals, bryozoans, polychaete worms, etc.). Terrestrial invertebrates are less well known, but Pleistocene sediments on San Miguel Island and Santa Rosa Island have innumerable shells of the air-breathing gastropod *Helminthoglypta ayresiana*.

Phylum Mollusca: Class Bivalvia (clams, oysters, etc.)

CHIS has excellent bivalve records from all five islands, particularly for the Quaternary (Figure 29). Pleistocene bivalves and gastropods from the islands' marine terraces are of special interest because the assemblages provide information on climate conditions such as water temperature. Muhs and Groves (2018), which documents the otherwise often overlooked fossils of Anacapa Island and Santa Barbara Island, shows that apparent mixing of cool- and warm-water species on the lowest terrace is a result of two marine occupations of the terrace, one at approximately 120 ka with warm water and a more recent occupation at 100 ka with cool water. Muhs et al. (2014) used mollusk fossils on San Miguel Island and Santa Rosa Island to look at uplift, and observed the same faunal discrepancy indicating terrace reoccupation. The majority of the fossil bivalve taxonomic diversity of the islands comes from Pleistocene deposits (Appendix A). The only reported fossil bivalves from Anacapa Islands and Santa Barbara Island are Pleistocene in age, documented in Valentine and Lipps (1963), Lipps et al. (1968), and Muhs and Groves (2018). The other three islands have more formations and a broader spread, although most non-Pleistocene records come from the Vaqueros Formation–Rincon Formation stratigraphic interval. The only other units from which bivalve taxa have been reported in any great numbers are the Beechers Bay Formation of San Miguel Island (Bremner 1933; Weaver and Doerner 1969b), and the Pozo, Cañada, and San Onofre Breccia formations of Santa Cruz Island.

Figure 29. Bivalves from Santa Rosa Island. All are from the Miocene sirenian site except for A, which is a loose cobble found at the mouth of a canyon (NPS/JUSTIN TWEET). **A.** A pectinid is exposed in this fossiliferous cobble. **B** and **C.** Two views of a cobble with oysters. **D.** A large loose clam.

Nine pre-Quaternary bivalve taxa have been named from fossils found on CHIS islands: *Ostrea englekyi*, *Ostrea haleyi*, *Ostrea loeli*, *Ostrea miguelensis*, *Ostrea wiedeyi*, *Pecten* (*Lyropecten*) *miguelensis*, *Pecten miguelensis* var. *submiguelensis*, *Placunanomia granti*, and *Pteria rositae* (see Appendix B for details). Most of them have since been reassigned to different genera. The great majority were named in Hertlein (1928), with the exceptions of *Pecten* (*Lyropecten*) *miguelensis* (Arnold 1906) and *Pecten miguelensis* var. *submiguelensis* (Loel and Corey 1932). Six were found in the Vaqueros or Rincon formations of Santa Rosa Island, two came from the Vaqueros or Rincon formations of San Miguel Island (*P.* (*L.*) *miguelensis* and *Ostrea miguelensis*), and one came from the Pozo Formation of Santa Cruz Island (*Ostrea haleyi*).

Phylum Mollusca: Class Gastropoda (snails)

Gastropods are by far the most diverse group of invertebrates found in the rocks of CHIS (Figure 30) (Appendix A). It is interesting to note, though, that this great diversity is also strongly concentrated in the Quaternary; Santa Cruz Island is the only island with significant stratigraphic distribution of gastropods. On San Miguel Island, gastropods have only been reported from the South Point Formation, Vaqueros/Rincon Formation, and Quaternary deposits. On Santa Rosa Island, gastropods are only reported from the Vaqueros Formation, Rincon Formation, and Quaternary deposits. They are entirely limited to the Quaternary on Santa Barbara Island, and are almost entirely limited to the Pleistocene on Anacapa Island outside of a report of poorly preserved gastropods in siltstones interfingered with the Miocene volcanic rocks (Scholl 1959).

Gastropod fossils have been utilized to study the same ecological and tectonic questions as bivalves. Six taxa have been named from fossils found on CHIS islands. Under their original names, they are *Alectrion churchi*, *Calliostoma augustinensis*, *Fissurella rixfordi*, *Micrarionta facta* form *intermedia*, *Helminthoglypta ayresiana lesteri*, and *Turritella tritschi* (Appendix B). All but the Pleistocene-age *H. a. lesteri* (Cockerell 1938a) and *M. f. intermedia* (Pilsbry 1939 ex. Hemphill ms.) were named by Hertlein (1928) from the Vaqueros/Rincon interval of San Miguel Island or Santa Rosa Island. Cockerell's terrestrial subspecies, now generally sunk into *H. ayresiana*, has been noted for its great abundance since the report of Bowers (1878; as *Helix ayresiana*). The recently extinct and living terrestrial snails of the northern Channel Islands are almost entirely different from what has been found on Santa Barbara Island. Instead, the Quaternary terrestrial snails of Santa Barbara Island are comparable to the terrestrial snails of the other southern Channel Islands, in particular San Nicolas Island (see for example Roth and Sadeghian 2006).

Phylum Mollusca: other mollusks

Three other groups of mollusks have been reported from the rocks and sediments of CHIS: cephalopods, chitons, and scaphopods. Only the chitons have been found in any significant numbers or diversity, and they have only been found in Quaternary sediments. Chitons, of the class Polyplacophora, are generally grazing mollusks somewhat like limpets, except their shells are composed of eight articulating valve segments permitting greater flexibility. All five islands have Quaternary records of multiple chiton taxa (Appendix A). Cephalopods, including the chambered nautilus, octopuses, squids, and allies, are better known from Paleozoic and Mesozoic rocks due to the abundance of now-extinct cephalopods with hard shells or internal structures (ammonoids, many nautiloid groups, belemnites, etc.). Within CHIS, cephalopods have been reported from the Cañada Formation of Santa Cruz Island (the extinct nautiloid *Eutrephoceras*; Shapiro 1998) and late Holocene deposits on Santa Barbara Island (squid; Collins et al. 2018b). Scaphopods, also known as "tusk shells" for their slender, gently curved, elongate conical shells, have been reported from the Vaqueros Formation of Santa Cruz Island (*Dentalium* sp.; Bereskin and Edwards 1969) and Pleistocene deposits on Anacapa Island (*Dentalium* cf. *D. pretiosum*; Valentine and Lipps 1963).

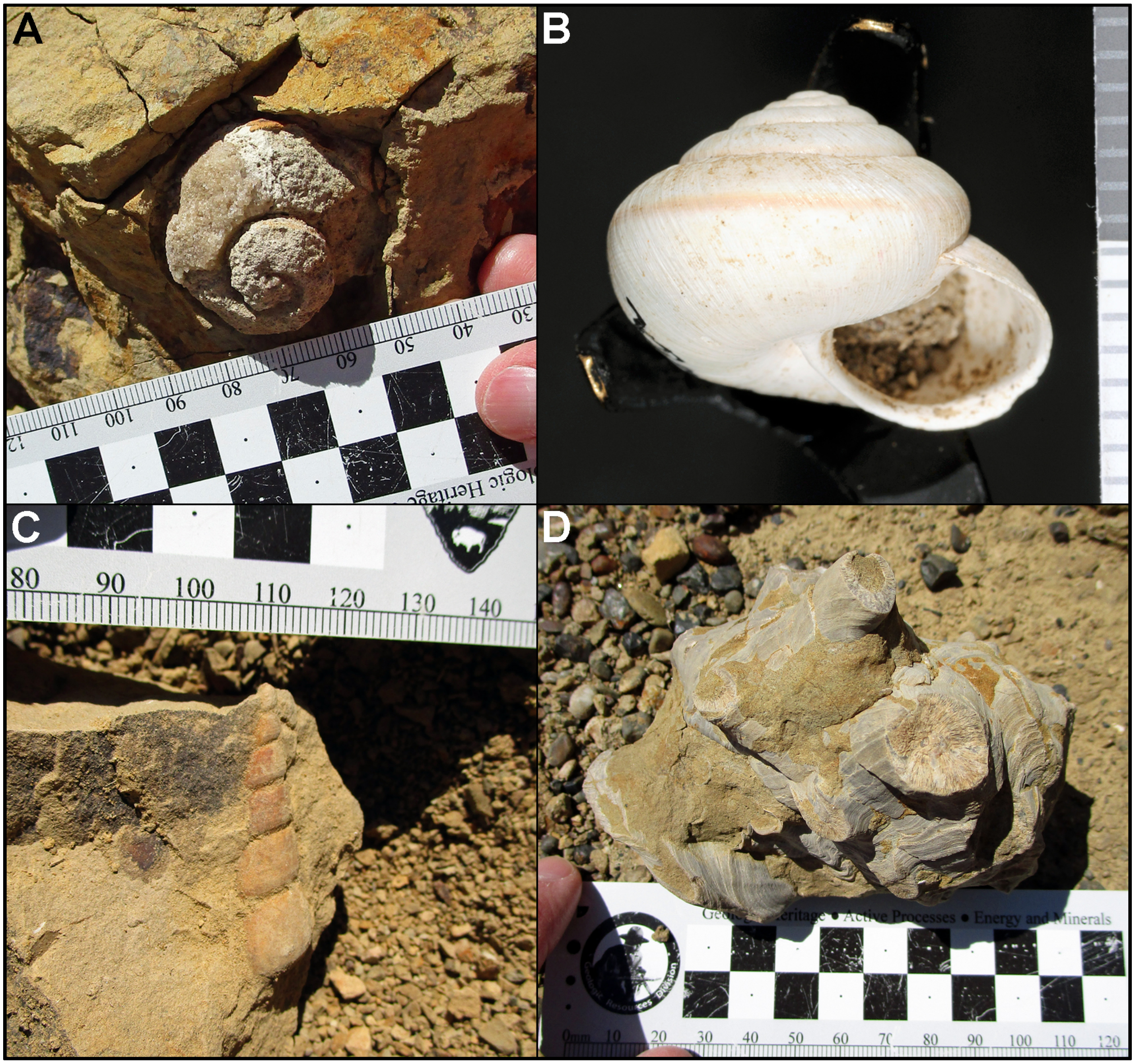

Figure 30. Various gastropods. A, C, and D are from the Miocene sirenian site on Santa Rosa Island (NPS/JUSTIN TWEET), and B is from the Pleistocene of San Miguel Island (ANSP). **A.** An internal mold of a large gastropod poking out of a rock. **B.** ANSP 170430, the holotype of *Helminthoglypta ayresiana lesteri*, with color band visible. **C.** A *Turritella* in a cobble. **D.** A partial *Rapana*.

Phylum Arthropoda (insects, spiders, crustaceans, etc.)

Fossils of arthropods representing several groups have been reported from all five islands of CHIS, but have generally not been reported in great detail. Five groups have been documented: barnacles, crabs, diplopods (millipedes), insects, and ostracodes ("seed shrimp").

Barnacles, also known as cirripeds, are primarily known from Quaternary deposits, from which specimens have been documented on all five islands. A few have also been reported from older rocks: the Rincon Formation of San Miguel Island (Loel and Corey 1932; Bremner 1933), the Vaqueros Formation of Santa Rosa Island (Loel and Corey 1932) and Santa Cruz Island (Loel and

Corey 1932; Bereskin and Edwards 1969), the San Onofre Breccia of Santa Cruz Island (Bereskin and Edwards 1969; Fisher and Charlton 1976), and the Monterey Formation of Santa Cruz Island (Bereskin and Edwards 1969).

Crab fossils have been reported from all of the islands, exclusively from Quaternary sediments except for one record in the South Point Formation of San Miguel Island (Kies 1982) and specimens observed eroded from the Vaqueros or Rincon Formation on Santa Rosa Island (Figure 31) (J. Tweet, pers. obs., June 2019). They are documented from the Quaternary sediments of Anacapa Island (Muhs and Groves 2018; San Diego Natural History Museum records), San Miguel Island (Ainis et al. 2011; Erlandson et al. 2011), Santa Barbara Island (Collins et al. 2018b; Muhs and Groves 2018), and Santa Cruz Island (San Diego Natural History Museum records).

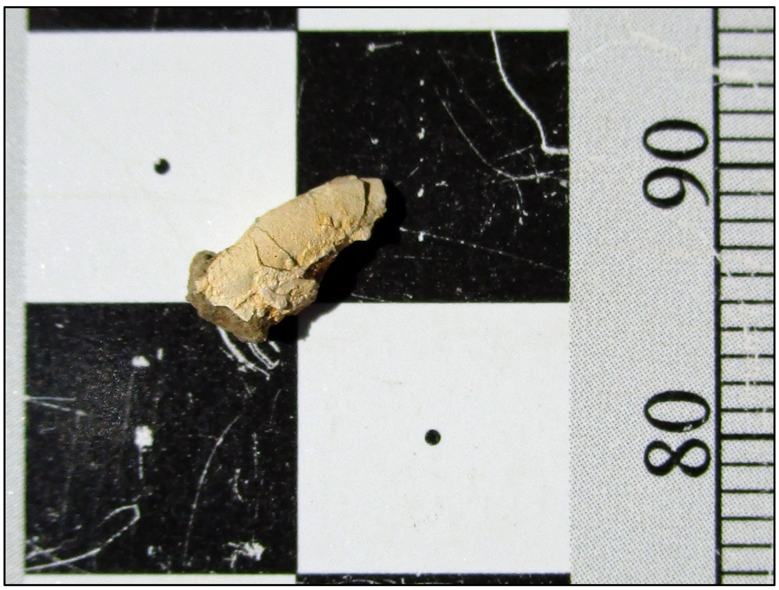

Figure 31. Part of a crab claw from either the Vaqueros or Rincon Formation, observed at the sirenian site on Santa Rosa Island (NPS/JUSTIN TWEET).

Reports of insects are limited to the beetle *Eleodes* sp. in Pleistocene sediments of Anacapa Island (possibly a modern contaminant) (Lipps 1964), late Pleistocene beetles and other insects at Santa Cruz Island, which also provided the millipede record (Grant 2016), and insects in late Holocene sediments from Santa Barbara Island (Collins et al. 2018b).

Finally, ostracodes have been reported from four of the islands. These minute bivalved crustaceans can be valuable paleoenvironmental indicators, but as microfossils require specialized processing and equipment before they can be studied. Undetermined ostracodes have been reported from the South Point Formation of Santa Rosa Island (Weaver and Doerner 1969a) and Pleistocene sediments of Anacapa Island (San Diego Natural History Museum records). Freshwater ostracodes are present in Pleistocene–Holocene fluvial sediments on Santa Rosa Island (Schumann et al. 2016) and Holocene sediments on Santa Cruz Island (Snyder 2000). Lipps et al. (1968) described small ostracode assemblages from Pleistocene terrace deposits on Santa Barbara Island.

Phylum Echinodermata: Class Echinoidea (sea urchins)

The only echinoderms to have been reported from CHIS rocks and deposits are echinoids, although it is not impossible that material from another echinoderm class may eventually be found; other Cenozoic echinoderm classes include Asteroidea (sea stars), Crinoidea (sea lilies and feather stars), Holothuroidea (sea cucumbers), and Ophiuroidea (brittle stars). The primary difficulty in recognizing specimens of these other classes is that their skeletons do not hold together after death as well as echinoid tests, and usually disintegrate into numerous tiny pieces. Echinoid fossils representing a number of taxa have been reported from all five islands (see Appendix A for details). All of the islands have Quaternary examples, primarily *Dendraster* and *Strongylocentrotus*. San Miguel Island, Santa Cruz Island, and Santa Rosa Island also have older Cenozoic echinoids. An assemblage of at least ten taxa is known from the Vaqueros Formation of Santa Rosa Island (Loel and Corey 1932; Grant and Hertlein 1938). Grant and Hertlein (1938) named *Brissus kewi* and *Lytechinus coreyi* from among this group.

Other Groups

Several other invertebrate groups have been reported less frequently than the previous. Due to the focus on mollusks, it is not clear if these other groups were actually as rare as the number of records suggests, or if they are simply under-reported and under-studied.

Phylum Porifera (sponges)

In general, sponges have a poor fossil record compared to their extant abundance and diversity, due primarily to the absence of macroscopic hard parts in many species. Many do have mineralized spicules, but these structures are microscopic and usually disaggregate as a sponge decays. Fossils of undetermined sponges have been reported from the Quaternary of San Miguel Island (Ainis et al. 2011) and Santa Rosa Island (Anderson et al. 2010; specifically stated to be spicules).

Phylum Cnidaria: Class Anthozoa (corals)

Most reports of fossil stony corals from CHIS pertain to the solitary cup coral *Balanophyllia elegans*, found in Quaternary deposits on San Miguel Island (Muhs et al. 2014), Santa Barbara Island (Muhs and Groves 2018), Santa Cruz Island (Pinter et al. 1998), and Santa Rosa Island (Muhs et al. 2014, 2015). One of the reasons for the numerous reports of this species may be its potential utility in uranium-series dating, as discussed in Muhs et al. (2014, 2015) and Muhs and Groves (2018). Only a few pre-Quaternary reports of corals have been made from CHIS, mostly from Santa Rosa Island. *Astrangia* sp. is known from the Vaqueros Formation of this island (Avila and Weaver 1969), and the report of *Oculina panzana* made by Loel and Corey (1932) may also have come from this formation. Undetermined corals have been reported from the Rincon Formation of Santa Rosa Island (Avila and Weaver 1969). The only other report of pre-Quaternary corals is *Balanophyllia* cf. *B. variabilis* from the Cañada Formation of Santa Cruz Island (Shapiro 1998).

Phylum Bryozoa (moss animals)

Bryozoans, also known as “moss animals” for their encrusting habits, are colonial animals both much smaller and more complex than coral animals; the dwelling chambers of bryozoan zooids look like pinpricks on the surface of the colony. A handful of bryozoan records exist for several formations on three CHIS islands. Undetermined bryozoans have been found in the Rincon Formation of San

Miguel Island (Bremner 1933), the Vaqueros Formation of Santa Cruz Island (Bereskin and Edwards 1969), and the Potato Harbor Formation of Santa Cruz Island (Weaver and Meyer 1969). The records of the San Diego Natural History Museum identify *Celleporina* sp. from the Quaternary of Santa Cruz Island and several taxa from the Pleistocene of Anacapa Island.

Phylum Brachiopoda (lamp shells)
Brachiopods, also known as "lamp shells" because some resemble ancient oil lamps, broadly resemble bivalves but are much different anatomically; one salient difference is that the two valves of a brachiopod are rarely mirror images, unlike the valves of bivalve mollusks. There are two reports of brachiopods from middle Cenozoic rocks of CHIS: *Hemithyris* sp. from the shale member of the Monterey Formation of San Miguel Island (Weaver and Doerner 1969b) and *Discinisca* sp. from the Vaqueros Formation of Santa Cruz Island (Bereskin and Edwards 1969).

Phylum Annelida (segmented worms)
Fossil polychaete worm tubes have been reported from four islands: the Vaqueros Formation of Santa Rosa Island (Loel and Corey 1932); the Pozo and Cañada formations of Santa Cruz Island (Shapiro 1998); the Quaternary of Anacapa Island (Muhs and Groves 2018); and potentially the Quaternary of Santa Barbara Island (Muhs and Groves 2018).

Fossil Vertebrates

All five islands have vertebrate fossils, primarily from late Pleistocene–Holocene deposits. Indeed, outside of Santa Cruz Island and the recent discovery of sirenian fossils in the Miocene of Santa Rosa Island, identifiable vertebrate remains have been limited to the late Quaternary. Pleistocene vertebrate fossils mostly pertain to birds or terrestrial mammals. The islands host both the most outstanding bird fossil record in the National Park Service, and a small but unique mammalian fauna of island endemics. This is not atypical for islands, which can only be reached by land-based animals under special circumstances but are easily reached by flying animals. Transitioning to the Holocene, the vertebrate record develops an anthropogenic signal due to the long history of human occupation and use of the islands, such as the remains of marine animals captured and processed by humans, and bones of animals introduced to the islands by humans intentionally (e.g., dogs) and unintentionally (e.g., the modern deer mice). Although Santa Cruz Island has the best stratigraphic record of vertebrates of the CHIS islands, it also has a relatively poor taxonomic record, lagging far behind the two other large islands. Notably, it has the smallest reported avifauna of any of the islands of CHIS. The relative rarity of Quaternary vertebrates can be attributed in part to less exploration of Santa Cruz Island; because it was part of the same landmass as San Miguel Island and Santa Rosa Island during the late Pleistocene, it seems reasonable to expect that similar Pleistocene fossils may be found there as well. In addition, although it has great topographic diversity, Santa Cruz Island does not have many deep canyons exposing thick deposits of fossiliferous sediment, as are seen on Santa Rosa Island (R. S. Anderson, pers. comm., April 2020).

Cartilaginous and Ray-Finned Fishes

Although CHIS is an island park, fish fossils are to date a minor constituent of the fossil record. It would not be surprising if their bones are actually more abundant and diverse than known, and they simply have not been a major research focus. Fishes have been reported from all five islands, primarily from the Quaternary, with the best records from San Miguel Island and Santa Rosa Island. On San Miguel Island, more than 27,000 fish specimens, primarily from ray-finned fishes, have been recovered from early Holocene cave deposits. Although this record has both bird and human influences, the fish record is thought to be primarily anthropogenic (Rick et al. 2001). Erlandson et al. (1999, 2011) reported smaller fish assemblages from anthropogenic shell middens of similar age on Santa Rosa Island. Pre-Pleistocene records include chondrichthyan teeth from the Cozy Dell and Vaqueros formations of Santa Cruz Island (Bereskin and Edwards 1969; Shapiro 1998), isolated actinopterygian remains in the Rincon Formation (Shapiro 1998) and the Monterey Formation (Weaver and Meyer 1969) of Santa Cruz Island, fish debris in the South Point Formation (Weaver and Doerner 1969a) and Rincon Formation (Avila and Weaver 1969) of Santa Rosa Island, and chondrichthyan teeth from the sirenian site on Santa Rosa Island (Hoffman 2017).

Amphibians and Reptiles

Aside from a late Holocene, pre-Spanish record of the night lizard *Xantusia riversiana* on Santa Barbara Island (Collins et al. 2018b), amphibian and reptile material is limited to the late Quaternary of San Miguel and Santa Rosa Island. Amphibians are represented by the chorus frog *Pseudacris*, found in latest Pleistocene deposits on Santa Rosa Island and Holocene deposits on San Miguel Island (Mead et al. 2018), and the lungless salamander *Batrachoseps* from the latest Pleistocene of Santa Rosa Island (Mead et al. 2004). Reptiles from Santa Rosa Island include the alligator lizard *Elgaria multicarinata* and indeterminate reptile specimens from an earliest Holocene midden (Erlandson et al. 1999), and the rattlesnake *Crotalus viridis* from the late Pleistocene (Guthrie 1998). Reptiles from San Miguel Island include *Elgaria multicarinata*, the gopher snake *Pituophis melanoleucus*, and *Crotalus viridis* from the Holocene (Guthrie 1993), *C. viridis* in Pleistocene eolian deposits (Guthrie 1998), *E. multicarinata* from an early Holocene barn owl roost (Guthrie 2005), and lizards probably including *E. multicarinata* and *Sceloporus occidentalis becki* from Holocene deposits (Ainis et al. 2011).

Class Aves

The late Pleistocene–Holocene avian record of CHIS is easily the best avian record for any NPS unit, and its significance extends beyond the NPS: Guthrie (1998) described the CHIS record as the most complete West Coast avifauna of the late Pleistocene. Dozens of species have been recognized from multiple sites on four of the five islands, capturing the transition from Santarosae to the modern islands and through shifting patterns of human usage. The island with the best-known and most thoroughly studied avifauna is San Miguel Island, which was the subject of a series of inventories prepared by Daniel Guthrie (Guthrie 1980, 1992, 1993, 1998, 2005; Collins et al. 2018a). As described in Guthrie (1998), San Miguel Island bird fossils derive from two main settings: a rock shelter with a mixed archeological and raptor site record dating back to at least 15,780 ± 120 radiocarbon yr BP (19,3780–18,780 cal yr BP) (Erlandson et al. 1996); and unconsolidated late Pleistocene eolian deposits in the northern part of the island. Aside from the quantity and diversity of specimens (Figure 32), the San Miguel Island avifauna is also of significance for its dating control (Erlandson et al. 1996), which allows detailed reconstructions of the fauna over short periods of time, and fine resolution on appearance and disappearance of taxa.

Figure 32. A drawer in LACM collections mostly containing bird specimens from San Miguel Island. Detailed locality information has been redacted from specimen cards (NPS/JUSTIN TWEET).

Santa Rosa Island also has a significant avifauna, although not as large in terms of species or specimens as San Miguel Island (Collins et al. 2018a). A large late Holocene assemblage has recently been described from Santa Barbara Island (Collins et al. 2018b), and a smaller Pleistocene avifauna was reported from Anacapa Island (Lipps 1964). Santa Cruz Island is the only island where bird remains are scarcely known; the San Diego Natural History Museum has a handful of unpublished Pleistocene specimens.

The study of CHIS fossil birds began with Hildegarde Howard's report on a small number of duck and goose bones found during excavation of mammoth fossils on Santa Rosa Island (Howard 1944). A handful of publications specifically on bird fossils were issued during the 1960s: Miller et al. (1961) on *Chendytes* bones from Anacapa Island; Howard (1962) on a caracara from Santa Rosa Island; Howard (1964a) on *Chendytes* from Anacapa; and Howard (1964b) describing *Asio priscus* from Santa Rosa Island. 1967–1968 excavations on San Miguel Island made by Natural History of Los Angeles County Museum staff under Charles Rozaire provided the basis for the original inventory by Guthrie (1980), as well as the impetus for expanded collections on San Miguel Island and later Santa Rosa Island as documented in Guthrie's later publications.

Five extinct bird species have been reported from CHIS in the literature: the owl *Asio priscus*, the flightless sea duck *Chendytes lawi*, the puffin *Fratercula dowi*, the condor *Gymnogyps amplus*, and the gannet *Morus reyanus* (Collins et al. 2018a). *C. lawi* is one of the characteristic Quaternary organisms of CHIS. It is of particular interest because this flightless bird, found along the California coast, was exploited by humans for thousands of years before going extinct about 2,500 years ago, making it an exception to the "overkill" model of end-Pleistocene megafaunal extinctions in North America (Jones et al. 2008). The genus and species were named for a specimen found on the mainland, near Santa Monica (Miller 1925); since then, thousands of bones of this species have been found on CHIS islands, and a second, older species (*C. milleri*) with better flight capabilities has been named from San Nicolas Island (Howard 1955). *Asio priscus* was named from the Pleistocene of Santa Rosa Island (Howard 1964b). During the Pleistocene, several sea birds used San Miguel Island for nesting colonies. Four species (*Chendytes lawi*, *Fratercula dowi*, Cassin's auklet *Ptychoramphus aleuticus*, and ancient murrelet *Synthliboramphus antiquus*) are each represented by more than a thousand bones. *C. lawi* was a ground nester, while the three alcids nested in burrows (Guthrie 2005). Raptors also extensively utilized CHIS. Owls in particular made important unintentional contributions to the preservation of the CHIS fauna. For example, barn owl sites full of small vertebrate remains are major sources of fossils on San Miguel Island (Guthrie 1998), Santa Barbara Island (Collins et al. 2018b), and Santa Rosa Island (Guthrie 1998). Bald eagle roosts are also significant sites; eagles took larger prey than owls, from a wider area (Guthrie 2005).

Class Mammalia

All five of the islands of CHIS have some record of mammals, generally from the Quaternary (Appendix A). The record of Anacapa Island is currently limited to the "giant" deer mouse *Peromyscus anyapahensis* (White 1966) and undetermined mammal bones (Lipps 1964). The record of Santa Barbara Island is limited to the mainland deer mouse *P. maniculatus* from the late Holocene (Collins et al. 2018b) and the sea lion *Zalophus* sp. from a Pleistocene marine terrace (Lipps et al. 1968).

On the other three islands, again most records are Quaternary. The exceptions are the undescribed Miocene sirenian from Santa Rosa Island, a fragment of marine mammal bone (cetacean?) from near the sirenian site (Hoffman 2017), and a few reports from Santa Cruz Island: undetermined cetacean remains from the Vaqueros Formation (Bereskin and Edwards 1969), sedimentary rocks in the Santa Cruz Island Volcanics, and the Monterey Formation (Weaver and Meyer 1969), and an undescribed desmostylian from the Monterey Formation (Barnes and Aranda-Manteca 1997; Domning and Barnes 2007). The Quaternary records can be divided between marine mammals and terrestrial mammals. Because most of the sedimentary rocks and deposits of CHIS are marine in origin, it can be assumed that additional terrestrial mammal discoveries will be limited to the Quaternary, with the potential exception of the little-explored Sespe Formation of Santa Rosa Island. However, there is considerable potential for additional discoveries of marine mammals throughout the many marine formations, as shown by the recent sirenian discoveries on Santa Rosa Island (Figure 33).

A small assemblage of pinnipeds was described from a Holocene archeological site on San Miguel Island (Walker and Craig 1979), and a few others have been reported from Santa Rosa Island (Orr 1960; Mitchell 1966; Erlandson et al. 2011; Muhs et al. 2015) and Santa Cruz Island (San Diego Natural History Museum records). Undetermined Quaternary cetaceans have been noted in passing from San Miguel Island (Bremner 1933; Erlandson et al. 1996), Santa Cruz Island (San Diego Natural History Museum records), and Santa Rosa Island (Stock and Furlong 1928; Orr 1960).

Figure 33. Sirenian ribs from Santa Rosa Island in the collections of the SBMNH (NPS/JUSTIN TWEET).

A small characteristic assemblage of Pleistocene non-marine mammals is known from San Miguel Island, Santa Rosa Island, and to a lesser extent Santa Cruz Island. This includes the shrew *Sorex ornatus* (Guthrie 1998), the vole *Microtus miguelensis* (Guthrie 1998), the "giant" deer mouse *Peromyscus nesodytes* (Wilson 1936), the vampire bat *Desmodus stocki* (Guthrie 1993), and mammoths (see below). *M. miguelensis*, vampire bats, and mammoths went extinct on the islands at the close of the Pleistocene, and several other taxa were probably introduced by humans, including harvest mice, the mainland deer mouse *Peromyscus maniculatus*, ground squirrels, dogs, foxes, and skunks (Figure 34) (Rick et al. 2009). It was previously thought that the island fox *Urocyon littoralis* had been present on the northern Channel Islands before humans (Collins 1991). Re-study and revised dating of the apparent Pleistocene material found only Holocene specimens, at most 6,400 cal yr BP old, so the species may have been distributed entirely by humans. If it indeed was introduced during the middle Holocene instead of arriving during the Pleistocene, its appearance may correlate with the extinction of *Chendytes lawi* and *Fratercula dowi* (Rick et al. 2009).

The very limited pre-human mammalian fauna of the islands is additional evidence against a land connection (Johnson 1978). In the intersection of paleontology and archeology, CHIS has an unusual claim to fame: Arlington Man, the oldest well-dated human skeletal remains in the NPS and potentially all of North America. The remains have been dated by radiocarbon to 10,960 ± 80 radiocarbon yr BP (Agenbroad et al. 2005), or 13,010–12,710 cal yr BP, within the latest Pleistocene. For comparison, the youngest date for a pygmy mammoth is 11,030 ± 50 radiocarbon yr BP

(Agenbroad et al. 2005), 13,030–12,750 cal yr BP, substantially overlapping the potential range of Arlington Man.

Figure 34. A skunk skull found in Quaternary sediment on Santa Rosa Island. The damaged areas in the eye region are the result of parasites in the sinuses (NPS/JUSTIN TWEET).

Four mammal species have been named from fossils found within CHIS, all from Pleistocene sediments: *Elephas exilis*, the famous pygmy mammoth (Stock and Furlong 1928; now known as *Mammuthus exilis*); the vole *Microtus miguelensis*, found on San Miguel Island (Guthrie 1998); and the "giant" deer mice *Peromyscus anyapahensis* (White 1966) from Anacapa Island and *P. nesodytes* (Wilson 1936) from Santa Rosa Island. *P. nesodytes* was once present in great abundance but went extinct during the Holocene, perhaps less than a thousand years ago (Ainis and Vellanoweth 2012; Rick et al. 2012b). Larger than *P. maniculatus*, it may have proved easier prey for avian predators (Rick et al. 2012b).

Mammalia: Order Proboscidea

The pygmy mammoth (*M. exilis*) is the most famous example of paleontological resources from CHIS. Mammoth remains are most abundant on Santa Rosa Island, followed by San Miguel Island, then Santa Cruz Island, and finally a single tooth on San Nicolas Island (Roth 1996a). The San Nicolas Island occurrence may represent a specimen moved by people (Vedder and Norris 1963; Johnson 1978), and may pertain to a mainland mammoth rather than a pygmy island mammoth (Vedder and Norris 1963). Hundreds of localities within CHIS have yielded fossils of pygmy or Columbian mammoths, with more than 380 localities documented between 1995 and 2008 on the three large islands (Agenbroad 2009). Orr (1968) reported finding bones of at least 200 individuals within ten years of work on Santa Rosa Island, focused along the northwest coast. He had little luck elsewhere on the island, noting only three finds in the southern part of the island, although these did include two of the three partial articulated specimens he found. In his experience, jaws, leg bones, pelvic bones, shoulder bones and tusks were the most common bones, while ribs and vertebrae were relatively rare and less complete (Orr 1968). Besides the preponderance of isolated and disarticulated remains, mammoth fossils from the islands are also often fragile. This characteristic has been observed from the first reports (Stearns 1873; Voy 1890–1893a) up to the present: Larry Agenbroad estimated that only 40% of the specimens he encountered could be collected, the rest being too broken and weathered (D. Morris, retired CHIS archeologist, pers. comm., December 2019).

Pygmy mammoth paleobiology and the history of study have been detailed in several reports published since the 1994 discovery of the Rockwell mammoth (Roth 1996a; Agenbroad and Morris 1999; Agenbroad 1999a, 2001, 2009, 2012; Agenbroad et al. 2005, 2014; Muhs et al. 2015; Semprebon et al. 2016; Pigati et al. 2017; Smith and DeSantis 2018). The first report of mammoth bones from the Channel Islands is a mention of an "*Elephas*" tooth from "Santa Barbara Island" given to the California Academy of Sciences in April 1873 by W. G. Blunt, along with fossil shells from Santa Rosa Island (Anonymous 1873). A little more information was provided in a paraphrase of comments by R. E. C. Stearns in September of that year (Stearns 1873), which corrected the source island to Santa Rosa Island and related that Blunt had found the tooth in situ near a degraded tusk. From here, the story of this first specimen has become confused. Later authors have attributed the find to a U.S. Coastal and Geodetic Survey expedition in the early 1850s (Orr 1968; Roth 1996a) or 1856 (Agenbroad 1999a, 2001). This information does not appear in any work more contemporaneous with the find (e.g., Bowers 1878; Voy 1890–1893a; Yates 1890a, 1890b, 1902–1905; Hay 1927). Instead, Blunt told Voy that it was collected in 1871, near where Voy and Blunt collected additional material in 1890 (Voy 1890–1893a). Due to the cancellation of Voy's publication, this information was not widely circulated, although it is mentioned in passing in Fairchild (1897). Multiple surveying projects took place in the Channel Islands for decades; the 1850s dates may be the result of identifying W. G. Blunt with George William Blunt, a notable figure in the Coastal and Geodetic Survey. However, George William Blunt can hardly be the man who worked with Voy on Santa Rosa Island in 1890 because he died in 1878. W. G. Blunt remains mysterious, but can be distinguished as a person of similar name who worked for the Survey in the Channel Islands in the early 1870s.

Mammoth specimens were reported sporadically from the islands for the next few decades (Voy 1890–1893a; Yates 1902–1905; Gilbert 1910). During the late 1920s, D. Irma Cooke, part of a botanical expedition to Santa Rosa Island based out of the SBMNH, found a tusk. David Banks Rogers, a SBMNH archeologist, then notified Chester Stock of the CIT. Stock and Furlong collected additional fossils from northwestern Santa Rosa Island during 1927 and 1928. In 1928, they formally named and described the material (Stock and Furlong 1928), selecting a skull and mandible with tusks from the island to serve as the type specimen of their new species *Elephas exilis* (CIT 14). The CIT specimens are now at the LACM; unfortunately, Stock's field notes have been destroyed (Roth 1996a). The LACM made some collections on the islands, but their activity was cut off by the American entrance into World War II (quite directly, as noted above under "History of Paleontological Work at CHIS") (Agenbroad 2001).

Phil Orr of the SBMNH began annual expeditions to Santa Rosa Island in 1946, collecting mammoth fossils and archeological specimens (Orr 1956b). Orr was interested in the possible connection of the extinction of the pygmy mammoth and the appearance of humans. He proposed that the "fire areas" of the islands represented areas burned by people, and identified locations he interpreted as roasting hearths of butchered mammoths (Orr 1956a, 1956b, 1968; Orr and Berger 1966), putting the arrival of humans on the island perhaps 40,000 years ago or more (Orr 1968). Although his early date for human arrival and interpretation of fire sources have not been borne out, recent finds and new dates have also shown that the last mammoths of the island went extinct at essentially the same time that people first arrived, raising the possibility of some interaction, as Orr proposed (Agenbroad 2001; Agenbroad et al. 2005).

Orr's work on Santa Rosa Island ended during the 1960s. His efforts resulted in the collection of numerous specimens for the SBMNH (Roth 1996a). Access to Santa Rosa Island was restricted over the next two and a half decades by the landowners, Vail and Vickers Company (Agenbroad and Morris 1999), resulting in temporary cessation of paleontological work with the exception of Boris Woolley's collecting. Woolley, a member of the Santa Rosa Island ranching family, made an avocational collection of mammoth fossils during the 1970s; this collection was donated to the SBMNH in 1995 (Agenbroad 1999a; Agenbroad and Morris 1999). Also during this time frame, Louise Roth produced a dissertation using pygmy mammoth museum specimens (Roth 1982), and published on their growth (Roth 1984).

Interest in the pygmy mammoths, and paleontology in CHIS in general, was sparked again by the discovery of a nearly complete skeleton of *M. exilis* in June 1994 on Santa Rosa Island. This skeleton, known as the Rockwell mammoth, was found in the northeastern part of the island by San Diego State University professor Tom Rockwell and graduate student Kevin Colson while investigating the geology of the island (Agenbroad and Morris 1999; Agenbroad et al. 1999). When excavated, it proved to be an articulated and approximately 90% complete skeleton of an adult male individual in situ (Agenbroad 1998, 1999a; Agenbroad et al. 1999), perhaps 50 years old at the time of death, and dating to 12,840 ± 410 radiocarbon yr BP (16,420–13,920 cal yr BP) (Agenbroad et al. 2005). Not only is it the most complete specimen, it had not been redeposited; previously it had been argued that all known pygmy mammoth specimens had been redeposited, which would make associated radiocarbon dates equivocal (Agenbroad 1998). Sediment from the vicinity was processed for microvertebrate remains and yielded fish, salamander, bird, and vole bones (Mead et al. 2004).

Don Morris, who was involved in the discovery and excavation, provided details on this find in an oral interview conducted by authors Tweet and Santucci in June 2019. According to Morris, the site was discovered serendipitously. During work at the Arlington Man site, Rockwell asked to see a place to look at marine terraces. Morris suggested an area where there was also a sea cave he wanted to examine. The sea cave proved barren, but Rockwell discovered the mammoth nearby. The discovery of the Rockwell Mammoth began the long-term association of The Mammoth Site of Hot Springs with CHIS, beginning with Larry Agenbroad and continuing under Jim Mead, Justin Wilkins, and others. It also led to the institution of a pedestrian GPS survey of San Miguel, Santa Cruz, and Santa Rosa islands to locate more specimens. Between the initiation of the survey in

January 1996 and 2002, the survey found more than 140 new localities, and showed that Santa Rosa Island pygmy mammoths were not concentrated in a small area of the northwestern coast (Agenbroad 1999a).

Although other elephants have been called dwarf forms, *M. exilis* appears to be the only true dwarf mammoth (Agenbroad 2001). The average mass of *M. exilis* is estimated at a little more than 750 kg (1,750 lb), with a typical range of 500–950 kg (1,100–2,100 lb). The average shoulder height was 1.72 m (5.64 ft), with a typical range of 1.37–1.93 m (4.49–6.33 ft) (Agenbroad 2009); the largest published estimate is 2.35 m (7.71 ft) (Roth 1984). Orr (1956a, 1956b) thought that there may have been two species of pygmy mammoths on the islands, one a little less than 2 m (6 ft) tall at the shoulder, and one a little more than 1 m (4 ft) tall at the shoulder (Orr 1956b). More recent work by Agenbroad (2009) identified only one species of pygmy mammoth. The small size does not appear to be due to retention of juvenile features (paedomorphism) (Roth 1984), but could involve a combination of stunting and genetic reduction of size (Roth 1984, 1996a).

The Columbian mammoth, *Mammuthus columbi*, is probably the ancestor of *M. exilis* (Johnson 1978; Agenbroad 2012). Madden (1981) proposed distinguishing the island variety of the Columbian mammoth as *M. columbi orri*, but this has not received wider support. Originally, it was thought that the Imperial mammoth (*M. imperator*) was the ancestral species, but this species is taxonomically problematic (Agenbroad 2009). Roth (1984) found no particular trends in mammoth size over time, and suggested that the nearness to the mainland allowed multiple immigrations of larger mainland mammoths. Multiple dispersals of *M. columbi* are also postulated by other authors (Agenbroad 2012; Muhs et al. 2015; Pigati et al. 2017), with the possibility of multiple dwarfing events, complicating the description of *M. exilis* as a truly distinct biological species. The Larramendy mammoth, discovered in 2014 and excavated in 2016 from northwestern Santa Rosa Island, offers an interesting perspective on this question: it is intermediate in size between classic *M. columbi* and *M. exilis*, yet lived near the time of mammoth extinction on Santa Rosa Island at approximately 13,393 ± 80 cal yr BP. It may represent an individual at an intermediate point along the dwarfing process or a hybrid between *M. columbi* and *M. exilis* (Bugbee and Wilkins 2018).

The timing of mammoth introduction to the islands is not known, but the record of mammoth fossils goes back to at least approximately 83.8 ka (Muhs et al. 2015). Muhs et al. (2015) proposed that mammoths first arrived on the islands when sea level was lower during one of two glacial periods, approximately 150,000 years ago (Marine Isotope Stage 6) or 250,000 years ago (MIS 8), and that the mammoth population experienced at least one phase of land reduction similar to the Pleistocene–Holocene transition at the end of MIS 6. The timing of their extinction is much better constrained. As noted previously, the most recent dated pygmy mammoth remains from CHIS are from 11,030 ± 50 radiocarbon yr BP (13,030–12,750 cal yr BP) (Agenbroad et al. 2005). *M. columbi* was also present but rare during this time span (Agenbroad 2009). Understanding the chronology of CHIS mammoths is hindered by the general lack of stratigraphic data and geologic context (Pigati et al. 2017).

Larger *M. columbi* has not been found in Santa Rosa Island's central highlands and appears to have been confined to the less steep land of the surrounding former marine terraces, which may be due to biomechanical differences between the two species (Agenbroad 2012), although the distribution of mammoth bones may also be a function of the sedimentary history of the island (Schumann and Pigati 2019). Pygmy mammoths had lower centers of gravity than Columbian mammoths (Agenbroad 2012), their hip joints were located farther down and back (Thaler 1999), and their limbs were more flexed (Roth 1996a). These differences would have allowed *M. exilis* to traverse steeper grades (Agenbroad 2001, 2012) and provided better agility and stopping abilities (Roth 1996a). Dental microwear has given contradictory results about the diet of *M. exilis*: Semprebon et al. (2016) interpreted teeth as showing that *M. exilis* was a specialized browser on leaves and twigs compared to *M. columbi*, while Smith and DeSantis (2018) found that *M. exilis* had a more diverse diet with more hard items than *M. columbi*.

Unlike the other mammals found on the islands, mammoths would have had to arrive under their own power, being unlikely candidates for rafting or transportation by humans (Wenner and Johnson 1980). While previously it was assumed that the ancestral population must have arrived via a land connection, such a connection is very unlikely based on geography, and elephants are underrated swimmers that would have been capable of swimming the 6 km (4 mile) distance between the mainland and Santarosae during the Pleistocene sea level lowstands (Johnson 1978, 1980; Roth 1996a). Mammoths may have had a significant impact on the island ecosystems (Roth 1996a).

Ichnofossils

Relatively few trace fossils have been reported from CHIS, but more undoubtedly exist, particularly invertebrate burrows and trails, which generally attract little attention and are often difficult for the inexperienced observer to recognize.

Invertebrate ichnofossils have been reported from four islands. *Helicotaphrichnus commensalis*, a trace fossil produced by worms on shells, was reported from the Pleistocene of Anacapa Island by Kern et al. (1974), and the San Diego Natural History Museum has shell specimens with sponge borings of Pleistocene age from the island. From San Miguel Island, invertebrate burrows and general bioturbation have been reported from the Jalama, Pozo–Cañada, and South Point formations (Kies 1982; Bartling and Abbott 1983). Santa Cruz Island has invertebrate burrows and bioturbation in the Pozo and Cañada formations (Kies 1982); bioturbation in the Cozy Dell Shale (Kies 1982); the burrow *Thalassinoides* in the Vaqueros Formation (Shapiro 1998); and Pleistocene examples of clasts bored by pholadid bivalves (pholad borings; Weaver and Meyer 1969), the "corncob" ghost shrimp burrow *Ophiomorpha*, and sponge borings on shells (San Diego Natural History Museum records). On Santa Rosa Island, burrows and bioturbation have been reported from the Vaqueros and Beechers Bay formations (Howell and McLean 1976; Nuccio 1977; Dibblee and Ehrenspeck 1998; Nuccio and Woolley 1998) and at the sirenian site (Hoffman 2017). Pleistocene deposits on this islands have yielded pholad borings (Muhs et al. 2015) (Figure 35) and arthropod coprolites including termite frass (Grant 2016; Scott et al. 2017).

Vertebrate ichnofossils from the islands have all been produced by birds. Probable alcid nesting burrows have been found in Pleistocene deposits on San Miguel Island, as well as eggshells of multiple taxa (Guthrie 1993, 1998, 2005). Owl pellets and bird eggshells have been found in late Holocene sediments on Santa Barbara Island (Collins et al. 2018b). Finally, barn owl pellets have been found in Pleistocene sediments on Santa Rosa Island (Guthrie 1998). Strictly speaking, eggshells are not universally considered to be trace fossils, but as non-body-fossils which preserve evidence of biological activity, they are included here for convenience.

Figure 35. A cobble with several pholad borings, observed on Santa Rosa Island (NPS/JUSTIN TWEET).

Other Fossils

Relatively little attention has been given to microfossils at many parks, which is not surprising in light of the specialized equipment and techniques needed to properly study them. However, CHIS is a notable exception to this rule. The need to place the formations on the northern Channel Islands in chronological and paleoenvironmental contexts led the graduate students working there in the 1960s to incorporate microfossils into their studies. Extensive faunal lists can be found in the 1969 northern Channel Islands volume (Avila and Weaver 1969; Bereskin and Edwards 1969; Doerner 1969; Weaver 1969b; Weaver and Doerner 1969a; Weaver and Meyer 1969), and have been included in the appendix tables (Appendix A). Other discussions and lists can be found in Kemnitzer (1933), Lipps et al. (1968), Kies (1982), Miller (1983), and Molesworth and Sloan (1998). Microfossils are the most species-rich category of fossils in CHIS, and the most widely distributed in terms of stratigraphy. All five islands have some kind of microfossil record, and the great majority of the formations have yielded microfossils; exceptions include the Miocene rocks of Anacapa Island, the Beechers Bay Formation of San Miguel Island, the Middle Anchorage Alluvium and possibly the Jolla Vieja Formation of Santa Cruz Island, and the Sespe and Vaqueros formations of Santa Rosa Island. The bulk of the reported taxa are foraminifera, unicellular organisms sometimes described as "amoebas with shells". Other groups of some abundance in CHIS rocks and deposits include coccolithophores (phytoplankton which secrete calcitic plates of nanometer size called coccoliths, so tiny they are sometimes called "nannofossils"), and diatoms, photosynthetic "microalgae" with resistant cell walls of silica. Microfossils require little management action, but are certainly of great interest for paleoenvironmental and biostratigraphic studies. One species of foraminifera, *Globotruncana marianosi*, has been named from the Jalama Formation of San Miguel Island (Douglas 1969).

Cultural Resource Connections

There are many ways for paleontological resources to have connections to cultural resources. Examples of paleontological resources in cultural contexts include, but are not limited to: fossils used by people for various purposes, such as petrified wood used for tools, spear points, and other artifacts, or fossil shells picked up as charms or simply because they looked interesting; associations of prehistoric humans with paleontological resources, such as kill sites of mammoths, prehistoric bison, and other extinct animals; incorporation of fossils into cultural records, such as fossils in American Indian lore, "tall tales" of mountain men, and emigrant journals; and fossils in building stone. Kenworthy and Santucci (2006) presented an overview and cited selected examples of National Park Service fossils found in cultural resource contexts.

The Quaternary fossil resources of CHIS have a number of connections to cultural resources, because of the extensive utilization of the islands by humans beginning in the latest Pleistocene and continuing for the entire Holocene. The archeology of CHIS was recently summarized in Braje et al. (2010). There are more than 675 archeological sites on San Miguel Island alone, most of which are shell middens (Erlandson et al. 2007). The majority of these human associations with fossil resources are connections that occurred between contemporaries, such as the many ancient shell middens. Human inhabitants of the islands were eating shellfish, fish, sea birds, and pinnipeds, remains of all of which can be found in the shell middens (Erlandson et al. 1999, 2007, 2011). On San Miguel Island, they left the oldest documented shell midden in North America (approximately 11,600 ± 150 cal yr BP) (Erlandson et al. 1996). It should be noted that there is the potential to confuse bald eagle middens with human middens (Erlandson et al. 2007).

Aside from human consumption of animals that became part of the middens, shells, bones, and plant matter were used to make beads, tools, cords, and other artifacts (Fergusson and Libby 1963; Orr 1968; Guthrie 1980; Rick 2002; Vellanoweth et al. 2003; Reeder et al. 2008). Among these artifacts is a bead of the gastropod *Olivella* that is a Pleistocene fossil from 30,450 cal yr BP (Vellanoweth et al. 2003). The Chumash people used pieces of Monterey Formation chert sourced from Santa Cruz Island to make microdrills for producing *Olivella* shell-bead currency (Nigra and Arnold 2013); as the Monterey Formation in general contains abundant microfossils, the Chumash were probably inadvertently relying on a fossiliferous material for this task. Island foxes were intentionally buried by humans on several of the Channel Islands, including Santa Cruz Island and Santa Rosa Island (Collins 1991). People also brought organic materials from the mainland, which is how deer bones came to be present at an early Holocene site on San Miguel Island (Vellanoweth et al. 2003). While it is not known if people encountered live mammoths on the Channel Islands, there is evidence that the Chumash people attributed pygmy mammoth bones to an ancient people. Aside from the inclusion of two mammoth teeth in a burial on Santa Cruz Island, it seems that they avoided the mammoth bones (Cushing et al. 1984).

People from the historic period of occupation have also been interested in the fossils of the islands. For example, there is the Boris Woolley collection of mammoth fossils now at the Santa Barbara Museum of Natural History (Agenbroad 2012). Goodyear (1890) referred to possible fossil impressions in island stone used for facing corners on a house on Santa Cruz Island. Several kinds of fossils were observed in the ranch house yard on Santa Rosa Island during the June 2019 visit, including petrified wood, shells, and stones with pholad borings (Figure 36).

Figure 36. A stone in the ranch yard on Santa Rosa Island with numerous pholad borings (NPS/JUSTIN TWEET).

Museum Collections and Paleontological Archives

Museum Collections and Curation

Park Collections

Since 1994 (Agenbroad 2012), the CHIS paleontological collections have been maintained at the Santa Barbara Museum of Natural History (SBMNH; Santa Barbara, California) (Figure 37). As of early August 2019, there were 1,268 specimens from CHIS cataloged in the SBMNH database, which does not include uncatalogued fossil specimens held by permitted researchers or in backlog (J. Hoffman, pers. obs., August 2019). There is one CHIS type specimen in SBMNH collections, the holotype of the extinct vole *Microtus miguelensis* (SBMNH 191). Another significant specimen in the SBMNH collections is the Rockwell mammoth (Figure 38), a cast of which is on display along with the original skull. The SBMNH collections also include significant historical collections made on the three larger islands before they became part of CHIS. Historical collections include those made by Phil Orr for the SBMNH (approximately 130 specimens, mostly pygmy mammoth; J. Hoffman, pers. obs., August 2019), and 113 mammoth bones collected by Boris Woolley on Santa Rosa Island (Agenbroad 2012). Some early material was lost to a 1962 fire, which reportedly destroyed specimens and records associated with Bremner's work (Smith 1991). Jonathan Hoffman and Paul Collins (Curator of Vertebrate Zoology) are actively researching the paleontological resources from CHIS. The museum also currently has funding to address its catalog backlog, catalog archives that may predate the park, and digitize records. Archaeological investigations in Late Pleistocene deposits at Santa Rosa Island, both those conducted by Phil Orr in the 1960s and in 2000–2008 by John Johnson (Curator of Anthropology), produced a sizable collection of *Peromyscus nesodytes* skeletal elements, as well as smaller quantities of bird and *Sorex* fossils. The portion of the Late Pleistocene faunal assemblage excavated since 2000 is curated within the CHIS collection in the SBMNH anthropology department.

Figure 37. Part of the CHIS collection at the Santa Barbara Museum of Natural History (NPS/JUSTIN TWEET).

Figure 38. Elements of the Rockwell mammoth at the SBMNH (NPS/JUSTIN TWEET).

Collections in Other Repositories

Conversations with museum staff, reports in the literature, and searches of online museum collection databases show that, in addition to the SBMNH, at least eleven other institutions have paleontological specimens from the five CHIS islands as of spring 2020. In some cases, the fossils were collected before a given island became part of CHIS. While these fossils may not fall under NPS jurisdiction, they are certainly of interest for historical, scientific, and resource management purposes. In others, the fossils were collected after an island became part of CHIS. Sizeable collections exist at the California Academy of Sciences (CAS; San Francisco, California), Natural History Museum of Los Angeles County (LACM; Los Angeles, California), San Diego Natural History Museum (SDNHM; San Diego, California), University of California Museum of Paleontology (UCMP; Berkeley, California), and University of California, Santa Barbara (UCSB; Santa Barbara, California). Minor collections including fewer than approximately a dozen catalog numbers are held at the Academy of Natural Sciences of Drexel University (formerly the Academy of Natural Sciences of Philadelphia; ANSP; Philadelphia, Pennsylvania), Cincinnati Museum Center (CMC; Cincinnati, Ohio), Western Archeological and Conservation Center (WACC; Tucson, Arizona), and the Yale Peabody Museum of Natural History (YPM; New Haven, Connecticut). Vertebrate material formerly held by Northern Arizona University (Flagstaff, Arizona) as part of the Quaternary Studies Program was returned in 2009 (G. Gallenstein, museum curator, Flagstaff Area National Monuments, pers. comm., October 2019), but the university's Laboratory of Paleoecology still has charcoal and fossil pollen samples (R. S. Anderson, pers. comm., April 2020). The

Mammoth Site of Hot Springs (Hot Springs, South Dakota) has material on loan from CHIS. Contact information for these repositories is included in Appendix C.

The California Academy of Sciences (CAS) has 1,149 specimens in 339 catalog numbers for the islands of CHIS (C. Garcia, collections manager of geology, and M. Abarca, curatorial assistant, California Academy of Sciences, pers. comm., August and November 2019). Almost all of these fossils are mollusks from Miocene rocks, and most specimens came from Santa Rosa Island (218 catalog numbers), with lesser numbers from San Miguel Island (90) and Santa Cruz Island (31). Non-mollusks include a handful of echinoids, a *Serpula* specimen, a brachiopod, and four mammoth specimens under three numbers. Among these fossils are some collected by Voy and mentioned in his unpublished works (Voy 1890–1893a, 1890–1893b), those collected by Bremner and reported in his 1932 publication on Santa Cruz Island, and the mollusks described in Hertlein (1928, 1933), including 11 holotypes (see Appendix B). Some of the specimens were originally reposited at the California State Mining Bureau or Stanford. In addition to the cataloged specimens, the CAS also reposits microfossil collections made on the Channel Islands for the Union Oil Company. This material is "largely unidentified and unquantified" (C. Garcia, pers. comm., August 2019).

C. D. Voy (1890–1893a) reported sending mammoth specimens from Santa Rosa Island to the "Museum of the State Mining Bureau". A museum catalog (California State Mining Bureau 1899) bears this out, with five catalog numbers for mammoth specimens collected from Santa Rosa Island on October 27, 1890 (12288–12292). The catalog also lists "calcareous casts or concretions" of vegetation collected from San Miguel Island (12293), and a group of Quaternary and "Pliocene" fossil shells from San Miguel Island and Santa Rosa Island (12314–12336), which are congruent with fossils Voy observed (Voy 1890–1893a, 1890–1893b). The fossils held by the State Mining Bureau were transferred to the California Academy of Sciences in the mid-20th century, perhaps the 1960s (D. Moore, pers. comm., November 2019), and at least some of Voy's specimens are still extant in the CAS collections. The original CSMB numbers are associated with them in the CAS records.

The Natural History Museum of Los Angeles County has numerous vertebrate and invertebrate fossils from all five CHIS islands. These fossils include specimens collected by LACM personnel and specimens originally reposited at Caltech (denoted CIT, for California Institute of Technology) and UCLA, acquired when the LACM absorbed these orphaned collections. Santucci, Tweet, and David Bustos (White Sands National Park) observed and documented the vertebrate collections from CHIS in June 2019. All five islands are represented in the vertebrate collections, with the bulk of the material coming from Santa Rosa Island. The majority of the vertebrate fossils are pygmy mammoth bones primarily from Santa Rosa Island, or Quaternary bird or rodent bones from various locations; a notable exception is the Miocene desmostylian material from Santa Cruz Island (LACM 16439). The vertebrate collections also include historically significant Caltech specimens, such as the holotypes of *Mammuthus exilis* and *Peromyscus nesodytes* (Figure 39A). The LACM holds two other relevant vertebrate types, those of *Asio priscus* (owl) and *Peromyscus anyapahensis* (Figure 39B and 39C). Highlights of the invertebrate collection include Quaternary specimens from otherwise little-studied Anacapa and Santa Barbara islands, and the type specimens of two echinoids, *Brissus kewi* and *Lytechinus coreyi* (Grant and Hertlein 1938), formerly held at UCLA.

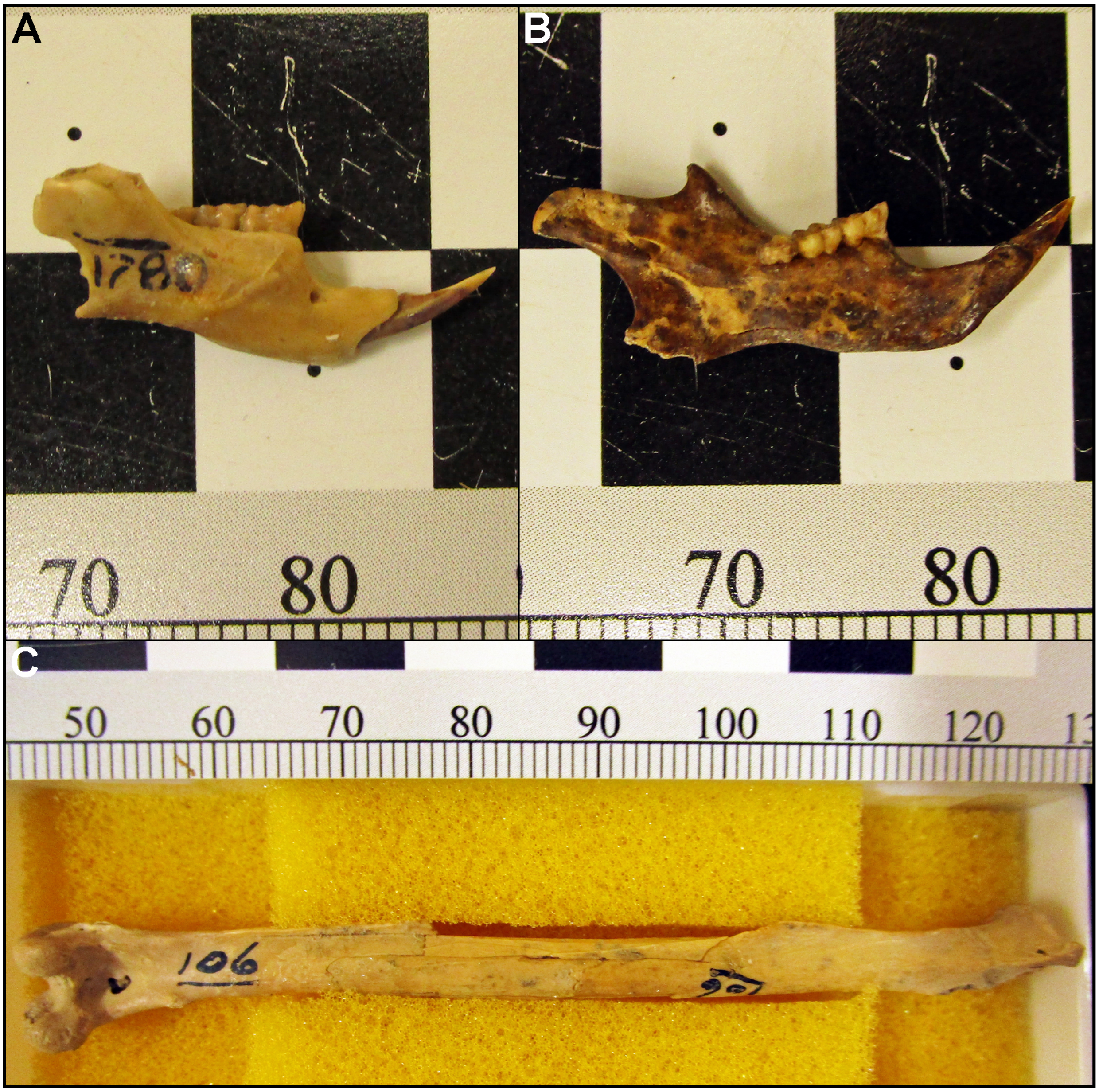

Figure 39. Three of the vertebrate type specimens from the CHIS islands at the LACM (NPS/JUSTIN TWEET). **A.** *Peromyscus nesodytes*, LACM (CIT) 1780; **B.** *Peromyscus anyapahensis*, LACM 9205; **C.** *Asio priscus*, LACM 4712.

The San Diego Natural History Museum holds Pleistocene specimens collected from Anacapa Island and Santa Cruz Island, as shown in their online collections database. There are 98 catalog numbers for fossils collected in 1997 by Nicholas Pinter from unnamed marine deposits on Middle Anacapa Island (specimens SDNHM 81529–81626). Most are mollusks, but there are also sponges, bryozoans, ostracodes, barnacles, echinoids, bony fish, a bird metacarpus, and foraminifera. For Santa Cruz Island, specimens came from three localities. One on eastern Santa Cruz Island produced fossils placed into 51 catalog numbers (SDNHM 81413–81463). These include sponges, bryozoans, chitons, bivalves, gastropods, barnacles, crabs, echinoids, trace fossils, and foraminifera. Two others are on western Santa Cruz Island. Collection at one of them in 2001 and 2002 produced fossils of birds and marine mammals, now cataloged as SDNHM 86080–86097. The other was visited in 2002 and produced primarily bivalves and gastropods, with corals, chitons, and echinoids. These fossils are cataloged under 46 numbers (SDNHM 120199–120245). One specimen which seemingly should be at this institution, the paratype of *Ostrea haleyi*, is given as San Diego Society of Natural History 427 (Hertlein 1933; Squires 2018), but no such specimen was found in the collections database.

The University of California Museum of Paleontology (UCMP) has a relatively small number of cataloged specimens from the islands of CHIS. The UCMP also reposits specimens formerly in the collections of USGS-Menlo Park, which have not been included in public databases. Paleontological localities on four of the five islands are included (the exception, Anacapa Island, is apparently represented only by recent localities). A single microfossil locality is reported from Santa Barbara Island. Santa Cruz Island is represented most notably by the plants described by Chaney and Mason (UCMP 413–426 and 398008–398011). There are also Miocene invertebrates (gastropods UCMP 410204 and 410205) and a Miocene shark tooth (UCMP 42490). The catalog also includes several former USGS-Menlo Park localities in middle Cenozoic rocks from Santa Cruz Island, but no specimens are yet reported for these localities. Twelve catalog numbers are given for specimens from San Miguel Island: invertebrates UCMP 12079 and UCMP 219354–219360; foraminifera UCMP 49003, 49006a, and 49006b; and *Mammuthus* UCMP 24052. Among the San Miguel Island specimens are the holotypes of bivalve *Pecten* (*Lyropecten*) *miguelensis* (UCMP 12079) and foram *Globotruncana marianosi* (UCMP 49003), originally reposited at Case Western Reserve University (Cleveland, Ohio) as CWRUHO13. In addition, there are a handful of former USGS-Menlo Park localities from San Miguel Island with no specimens yet reported. Finally, there are six UCMP catalog numbers for specimens from Santa Rosa Island: Miocene bivalves UCMP 10136 and 31737 and gastropod UCMP 31625 (UCMP 31737 is the holotype of *Pecten miguelensis* var. *submiguelensis*); Miocene gastropods UCMP 15257 and 15278; and *Mammuthus exilis* UCMP 39516. As before, there are also a number of former USGS-Menlo Park localities with no reported specimens for Santa Rosa Island.

The Department of Earth Science of the University of California, Santa Barbara maintains a collection of fossils from the islands of CHIS. These include: 562 lots of specimens occupying two cabinets, primarily from Eocene and Miocene rocks on Santa Cruz Island and Miocene rocks on Santa Rosa Island, including the collections described in Weaver et al. (1969a) (B. Tiffney, professor of plant paleobiology and professor of biology, University of California, Santa Barbara, pers. comm., August 2019); a mammoth femur from Santa Cruz Island (Cushing et al. 1984); and the specimens collected by Shapiro from Santa Cruz Island and described in Shapiro (1998), which were collected in 1996 and 1997 and make up 116 lots (B. Tiffney, pers. comm., August 2019).

Four other institutions are known to hold small collections of CHIS fossils. The type specimen of the gastropod subspecies *Helminthoglypta ayresiana lesteri* (Cockerell 1938a) is in the malacology collection of the Academy of Natural Sciences of Drexel University as ANSP 170430 (sometimes given as 170403a) (Figure 40). The malacology collection also holds five other *Helminthoglypta* specimens collected by Cockerell (ANSP 170431–170434 and paralectotype 465851), and the holotype and other specimens of gastropod *Micrarionta facta* form *intermedia*, now known as *M. intermedia* (Pilsbry 1939 ex. Hemphill ms.; ANSP 86840a per Roth 1996b, or syntypes ANSP 86824, 86831, and 86840 from Santa Barbara Island per the ANSP malacology database).

Figure 40. ANSP 170430, the holotype of *Helminthoglypta ayresiana lesteri* (ANSP photo).

A search of the invertebrate paleontology collections database of the Cincinnati Museum Center shows three fossil specimens from Santa Rosa Island (IP12632, *Ostrea vespertina loeli*; IP22190, *Turritella inezana*; and IP22203, *Turritella ocoyana*) and two specimens from Santa Cruz Island (IP10050, *Patella*; and IP67480, *Chrysodomus tabulatus*). All of these are Miocene mollusks.

During a visit to the NPS's Western Archeological and Conservation Center in 2015, Justin Tweet observed, recorded, and photographed two paleontological specimens that had been recovered from archeological contexts: CHIS 1357, a putative whale bone in two pieces (Figure 41A); and CHIS 1385, two mammoth tooth plate fragments (Figure 41B).

The catalog of the Yale Peabody Museum includes records for eight lots of foraminifera taken from cores drilled on or near Santa Cruz Island by the Richland Oil Company (YPM IP 530004 through YPM IP 530008, SBC-36; and YPM IP 529996 through YPM 529998, SBC-37), and 16 bryozoan specimens. The bryozoan specimens are reportedly from the Miocene of Santa Barbara Island, where no other Miocene macrofossils have been reported, and indeed no other Santa Barbara Island fossils are in the YPM records. They were collected by a J. Grady, who may be the same as a J. R. Grady who produced a master's thesis on the submarine geology of Santa Barbara Island in 1955. Provenance information is meager and indicates an association with a macrofossil bed (S. Butts, senior collections manager, Division of Invertebrate Paleontology, Yale University, Peabody Museum of Natural History, pers. comm., July 2019). Apparently Grady was specifically collecting bryozoans. All of the identified bryozoan taxa that could be traced are recent taxa only, which may suggest that Grady was collecting modern bryozoans living on Miocene rocks just offshore of Santa Barbara Island. Another possibility is that someone identified the taxa using only modern forms as a guide. In either case, the mention of a macrofossil bed is intriguing.

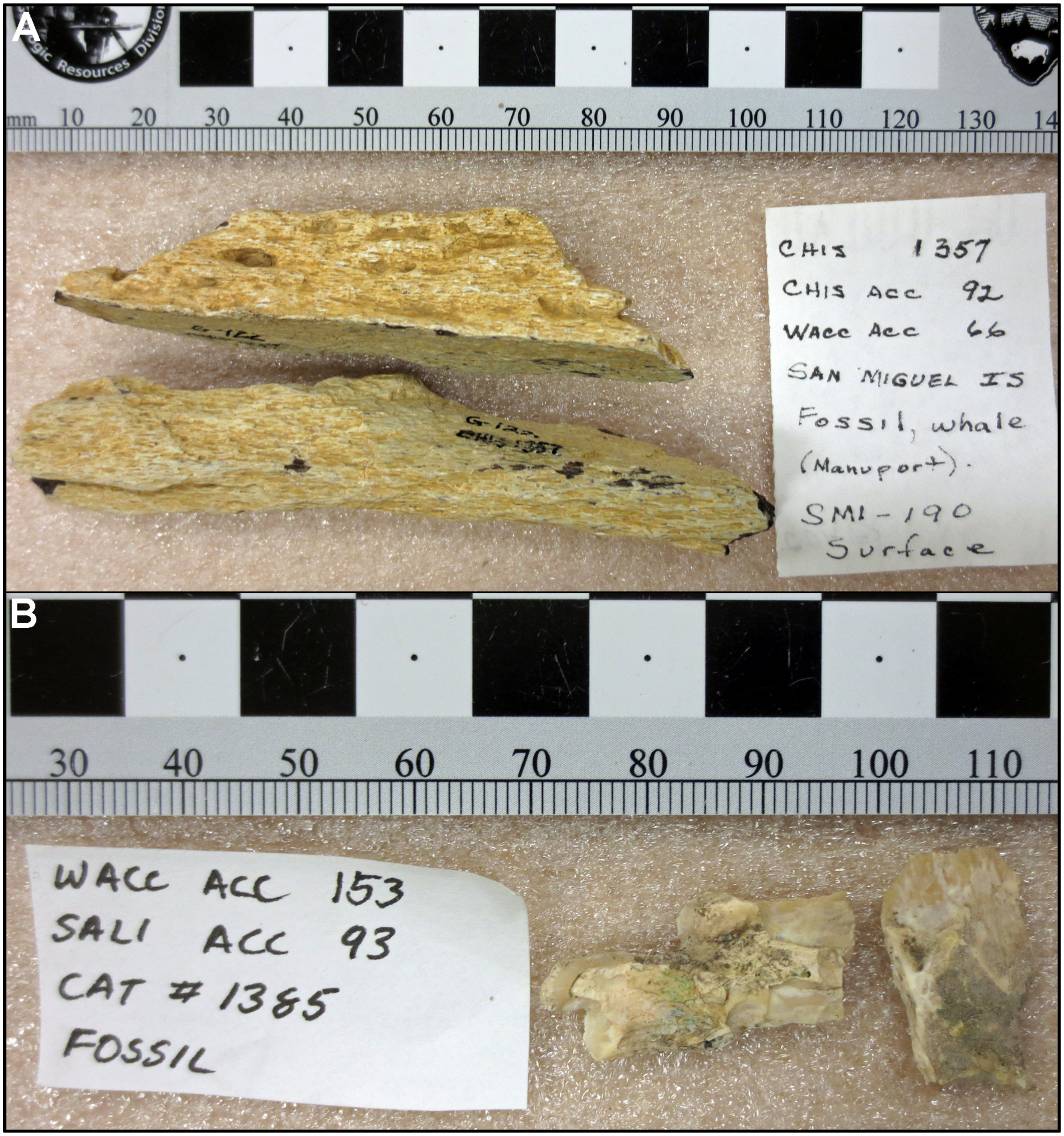

Figure 41. CHIS specimens at WACC (NPS/JUSTIN TWEET). **A.** CHIS 1357. **B.** CHIS 1385.

In addition to these collections, The Mammoth Site of Hot Springs has been involved in paleontological work at CHIS since 1994, when Larry Agenbroad brought a crew to excavate the Rockwell mammoth. At the time of Tweet's visit in early June 2019, Mammoth Site staff were preparing the Larramendy mammoth skull (Figure 42), and there was also microvertebrate material from CHIS on loan. The Mammoth Site exhibits a cast of the Rockwell mammoth.

Figure 42. The Larramendy skull in preparation at The Mammoth Site of Hot Springs (NPS/JUSTIN TWEET).

Type Specimens

Twenty-three fossil taxa have been named from specimens collected on the islands of CHIS: 17 invertebrates, five vertebrates, and a foraminiferan (Appendix B). Of these, the most famous by far is the pygmy mammoth *Mammuthus exilis*, originally *Elephas exilis*. The only species named from material collected from CHIS land after the park was established (proclaimed 1938 as a national monument) are *Microtus miguelensis* and *Peromyscus anyapahensis*. Although *Asio priscus* was named in 1964, it was based on material collected in the late 1920s or early 1930s (Howard 1964b), and from Santa Rosa Island, which did not become part of CHIS until 1980. *Globotruncana marianosi* was named in 1969, but from San Miguel Island, which also did not become part of CHIS until 1980. Fossil species have been named from all of the islands of CHIS, with the great majority coming from San Miguel Island and Santa Rosa Island. Most of the holotype specimens are held at either the California Academy of Science or the Natural History Museum of Los Angeles County, which account for 17 of the 23 taxa. The taxa are mostly invertebrates from Miocene rocks (bivalves, gastropods, and echinoids from the Vaqueros and Rincon Formations, 14 taxa) or Pleistocene vertebrates (five taxa).

Archives

NPS Paleontology Archives

All data, references, images, maps and other information used in the development of this report are maintained in the NPS Paleontology Archives and Library. These records consist of both park specific and servicewide information pertaining to paleontological resources documented throughout the NPS. If any resources are needed by NPS staff at CHIS, or additional questions arise regarding paleontological resources, contact the NPS Senior Paleontologist and Paleontology Program Coordinator Vincent Santucci, vincent_santucci@nps.gov. Park staff are also encouraged to communicate new discoveries to the NPS Paleontology Program, not only when support is desired, but in general, so that this information can be incorporated into the archives. A description of the Archives and Library can be found in Santucci et al. (2018).

E&R Files

E&R files (from "Examination and Report on Referred Fossils") are unpublished internal USGS documents. For more than a century, USGS paleontologists identified and prepared informal reports on fossils sent to the survey by other geologists, for example to establish the relative age of a formation or to help correlate beds. The system was eventually formalized as a two-part process including a form sent by the transmitting geologist and a reply by the survey geologist. Sometimes the fossil identifications were incorporated into publications, but in many cases this information is unpublished. These E&R files include documentation of numerous fossil localities within current NPS areas, usually predating the establishment of the NPS unit in question and frequently unpublished or previously unrecognized. Extensive access to the original files was granted to the NPS by the USGS beginning in 2014 (Santucci et al. 2014). Several E&R files exist for CHIS.

Photographic Archives

Conversations with staff at various repositories indicate that CHIS, The Mammoth Site of Hot Springs, the Natural History Museum of Los Angeles County, the Santa Barbara Museum of Natural History, and the Santa Barbara Botanic Garden have historic photos of paleontological work undertaken at CHIS. The NPS Paleontology Program maintains an archive of photos taken by its staff and actively encourages the acquisition of digital copies of other relevant photographs for its central archives.

Paleontological Research

Current Research

Beginning with 2012, the year the revised Mediterranean Coast Inventory & Monitoring Network Paleontological Resource Inventory Report (Tweet et al. 2012) was written, 18 permits have been issued for projects with some kind of paleontological component within CHIS or utilizing previously collected CHIS specimens. In some cases paleontology is a secondary focus of the project. In descending chronological order, the permitted projects include the following ("principal investigator" is the person listed as such in the Research Permitting and Reporting System [https://irma.nps.gov/RPRS/]; projects may have many more investigators and associated institutions):

CHIS-2012-SCI-0001, principal investigator Nicholas Pinter of Southern Illinois University–Carbondale, project "*Testing Hypotheses of Latest Pleistocene Paleo-environmental Collapse, Northern Channel Islands, CA*", issued for 2012–2013.

CHIS-2012-SCI-0006, principal investigator Courtney Hofman of the Smithsonian Institution, project "*Evolutionary History of the Island Fox: DNA, Isotopes, and Direct AMS 14C Dating of Archaeological Island Fox Bones*", issued for 2012–2014.

CHIS-2012-SCI-0010, principal investigator Scott Minor of the USGS, project "*Quaternary Geologic Mapping of Channel Islands National Park*", issued for 2012; this project was continued in succeeding years under permits CHIS-2014-SCI-2005 (2014), CHIS-2015-SCI-0005 (2015), and CHIS-2016-SCI-0011 (2016).

CHIS-2013-SCI-0010, principal investigator William Wilkins of The Mammoth Site of Hot Springs, project "*Research on the Pleistocene Megafauna of the Northern Channel Islands of California*", issued for 2013; this project was continued in succeeding years under permits CHIS-2014-SCI-0017 (2014), CHIS-2015-SCI-0006 (2015), and CHIS-2016-SCI-0013 (2016).

CHIS-2014-SCI-0014, principal investigator Paul Collins of the SBMNH, project "[redacted] *Excavations on Santa Barbara Island to Understand Prehistoric Faunal Changes on Santa Barbara Island*", issued for 2014; this project was continued in 2015–2016 under permit CHIS-2015-SCI-0019.

CHIS-2015-SCI-0010, principal investigator Todd Braje of San Diego State University, project "*Tracking Past and Present Sea Surface Temperature Changes Along San Miguel Island, California*", issued for 2015.

CHIS-2016-SCI-0003, principal investigator Christopher Jazwa of Penn State, project "Mytilus californianus *Sampling and Archaeological Site Survey on Northern Santa Rosa Island*", issued for 2016.

CHIS-2016-SCI-0017, principal investigator Daniel Muhs of the USGS, project "*Climate Change and Landscape Evolution in Channel Islands National Park*", issued for 2016–2019.

CHIS-2016-SCI-0019, principal investigator William Wilkins of The Mammoth Site of Hot Springs, project "*Large Specimen Recovery at the Larramendy Mammoth Locality, Santa Rosa Island*", issued for 2016.

CHIS-2016-SCI-0022, principal investigator Nicholas Pinter of UC-Davis, project "*Late Pleistocene to Holocene Paleoenvironmental Response of the Northern Channel Islands*", issued for 2016–2017.

CHIS-2017-SCI-0022, principal investigator Jonathan Hoffman of the SBMNH, project "*Stabilization of the First Fossil Sirenian Locality in the Channel Islands National Park*", issued for 2017.

Relevant permits active at the beginning of 2012 include:

CHIS-2007-SCI-2013, principal investigator Daniel Muhs of the USGS, project "*Climate Change and Landscape Evolution in Channel Islands National Park*", issued for 2007–2015; this project was continued in 2016–2019 under permit CHIS-2016-SCI-0017 (see above).

CHIS-2011-SCI-003, principal investigator R. Scott Anderson of Northern Arizona University, project "*Vegetation History of Santa Cruz Island*", issued for 2011–2015.

Paleontological Research Permits

See the National Park Service Natural Resource Management Reference Manual DO-77 section on Paleontological Resource Management, subsection on Scientific Research and Collection (https://irma.nps.gov/DataStore/Reference/Profile/572379). NPS Management Policies 2006, section 4.8.2.1 on Paleontological Resources, states that

> *The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit.*

Any collection of paleontological resources from an NPS area must be made under an approved research and collecting permit. The NPS maintains an online Research Permit and Reporting System (RPRS) database for researchers to submit applications for research in NPS areas. Applications are reviewed at the park level and either approved or rejected. Current and past paleontological research and collecting permits and the associated Investigator's Annual Reports (IARs) are available on the RPRS website (https://irma.nps.gov/rprs/). Additional information on NPS law and policy can be found in Appendix D.

Interpretation

CHIS staff recognize the importance of public interpretation and education of paleontological resources. Interpretation is particularly important at CHIS because public access to the islands is difficult. Travel to the islands is expensive, and exploring them in depth requires camping skills and equipment, all factors which impose socioeconomic constraints on visitation. On the other hand, there is anecdotal evidence that announcements of scientific discoveries have led to unauthorized resource collecting (D. Morris, pers. comm., July 2019). The remoteness of the islands presumably reduces the risk of theft and vandalism, but at the same time makes it difficult to readily monitor and protect sites. Therefore, public announcements of fossil discoveries and interpretation of paleontological resources must be presented with care and non-disclosure of specific resource locality information. Although paleontological and archeological resources are different, sound practices for protecting these resources in interpretive materials are quite similar. They include the restriction of detailed locality information to park staff and qualified researchers, previewing documents, and the inclusion of a protection message.

CHIS interpretation and education staff have actively interpreted and promoted the paleontological resources of the park through a wide variety of venues and media. CHIS provides excellent and focused interpretation of paleontological resources. There are interpretive and educational opportunities involving paleontology at the visitor center itself, including a cast of the Rockwell mammoth. CHIS participates in National Fossil Day activities and distributes Junior Paleontologist booklets and badges from the Junior Ranger program. There will be a page dedicated to paleontological discoveries in the new CHIS Junior Ranger booklet, including the visitors' role in protecting these resources. (M. Navarro, CHIS Education Coordinator, pers. comm., January 2020). Park staff also have physical resources available for off-site interpretation, including a fossil dig station that has been used at events with the La Brea Tar Pits (formerly the George C. Page Museum) and for the National Park Service centennial. CHIS previously participated in an annual event with the Page Museum, before changes at the latter institution.

Significant fossil finds such as the Rockwell mammoth and Larramendy mammoth have received media coverage on-site, facilitated by CHIS staff. CHIS staff have actively participated in media coverage and the production of educational materials related to these finds. For example, the park website maintains a series of videos about the Rockwell mammoth find at https://www.nps.gov/chis/learn/photosmultimedia/life-and-times-of-the-pygmy-mammoth.htm. More recently, with changes in how news stories are covered and staff reductions at various media outlets, CHIS staff have been even more proactive. For example, CHIS staff produced videos and photographs in-house for use by outside media for the Larramendy mammoth. In the case of the Larramendy mammoth, park media was important because the time necessary for a site visit made visiting difficult for outside media (Y. Menard, pers. comm., December 2019). CHIS staff also issue press releases for paleontological discoveries and news, such as the sirenian discovery, the Larramendy mammoth discovery, paleontological educational programs, and the passing of paleontologist Larry Agenbroad. Photographs and videos are produced to exclude features that may reveal provenience, and resource protection is included in messaging, while promoting resource stewardship.

CHIS's online presence includes a significant distance learning component. While the park reaches on the order of 20,000–30,000 schoolchildren annually at the visitor center, it reaches 120,000 through its distance learning programs. These programs are particularly important for reaching underserved youth. The park is actively developing and showing content to meet Next Generation Science Standards, including paleontological content (Y. Menard, pers. comm., December 2019). One example is a curriculum and ranger program ("Pygmy Mammoth HS 5E Unit") which is in use by local high school teachers (M. Navarro, pers. comm., July 2020). Another component involved filming Jorge Velez-Juarbe (LACM) working with the sirenian material for an educational video about this recent discovery (Y. Menard, pers. comm., December 2019). Educational programs are developed for the Channel Islands Live project (https://www.nps.gov/chis/planyourvisit/channel-islands-live-nps.htm), which supports live interactive programs, archived programs, distance learning, and webcams, featuring a variety of topics and allowing the public to experience the park remotely. The park's public lecture series, "From Shore To Sea", is also archived on its website (https://www.nps.gov/chis/planyourvisit/from-shore-to-sea.htm) and includes paleontological content, such as lectures on island mammoths and the sirenian discovery.

CHIS actively participates in National Fossil Day activities. The National Park Service coordinates the National Fossil Day partnership (https://www.nps.gov/subjects/fossilday/index.htm) and hosts fossil-focused events across the country, in conjunction with Earth Science Week (the second full week in October). National Fossil Day is celebrated annually on Wednesday of Earth Science Week. For 2020, October 14 is National Fossil Day. The NPS Geologic Resources Division (GRD) can assist parks with planning for National Fossil Day activities and provide supplies of Junior Paleontologist Program supplies including activity booklets, badges, posters and other fossil-related educational resources (https://www.nps.gov/subjects/fossils/junior-paleontologist.htm).

The SBMNH is also a venue for outreach on CHIS paleontological resources. The museum displays and interprets CHIS fossils, including a cast of the Rockwell mammoth in an environment that recreates the dig (Figure 43). It also regularly holds outreach events, such as demonstration tables, public talks (at the museum and at private organizations such as Rotary Clubs), school group visits, summer camps, watching preparation, and regular tours of the collections. Some of these events originate with the museum or are only held there, but it also collaborates with CHIS, for example on an educational video on the sirenian and Shore to Sea lectures at CHIS headquarters (J. Hoffman, pers. obs., January 2020).

Figure 43. The Rockwell mammoth display at the Santa Barbara Museum of Natural History, with field tools and notes to simulate the discovery, excavation, and study process (NPS/JUSTIN TWEET).

Current Long Range Interpretive Plan

The park does not currently have a long range interpretive plan (Y. Menard, pers. comm., December 2019).

Recommended Interpretive Themes

CHIS staff are already incorporating paleontology into a wide variety of interpretive and educational programs. A few ideas and suggestions from the national level are included below.

I. General Paleontology Information

Paleontology programs should include information instructing visitors how to be paleontologically aware while in the park. The ranger will provide the visitor with advice on why fossils are important, how paleontologists look for fossils, what to do if fossils are found, and reminders to be aware that fossils exist and should be respected within park boundaries.

- Fossils are non-renewable resources that possess scientific and educational information and provide insight into what the Earth was like thousands and even hundreds of millions of years ago.

- When paleontologists survey for paleontological resources, the most important tool is a geologic map. Paleontological resources are more common in certain geologic units, so knowing where those units are exposed is important for a successful search. Other tools that a paleontologist takes into the field include small picks and brushes, consolidants to stabilize fossils, GPS, camera, topographic maps, and appropriate First Aid and safety equipment. It might be helpful to provide examples of these items for visitors when giving an interpretive talk.
- If fossils are found in the park by a visitor, the visitor should photograph it and notify a ranger of where the resource was found, but most importantly, they should leave the fossil where they found it. It is extremely important for scientific and resource management purposes for locational information to be preserved. Visitors should be informed that park fossils are protected by law. This message is emphasized in paleontological and archeological education programs.

II. Fossils of CHIS

- This report can be used to amplify current CHIS educational and interpretive programs about the types of fossils present in the park and what they tell scientists about Earth's dynamic history, in order to increase visitors' understanding of local geology and paleontology. Information regarding fossils from the vicinity of CHIS can be included, which would be especially interesting as a story in contrasts: the terrestrial Quaternary fossils of the islands are very different from the nearby mainland. The CHIS paleontological record of environmental changes is also significant, as well as the stories fossils tell us about the early human occupation of the islands.

III. Caves and Fossil Resources

- CHIS has a number of caves, some of which contain significant paleontological resources. They also frequently contain archeological resources and are inhabited by living organisms, making them unique settings to discuss the intersection of geology, biology, and human activity, and how each affects the other. Because of the long history of human habitation at CHIS, cultural resources and late Quaternary paleontological resources are intertwined, particularly at caves.

Paleontological Resource Management and Protection

National Park Service Policy

Paleontological resources are non-renewable remains of past life preserved in a geologic context. At present, there are 419 official units of the National Park System, plus national rivers, national trails, and affiliated units that are not included in the official tally. Of these, 277 are known to have some form of paleontological resources, and paleontological resources are mentioned in the enabling legislation of 18 units, including CHIS. Fossils possess scientific and educational values and are of great interest to the public; therefore, it is exceedingly important that appropriate management attention be placed on protecting, monitoring, collecting, and curating of these paleontological specimens from federal lands. In 2009, the Paleontological Resources Preservation Act (PRPA) was signed into law as part of the Omnibus Public Land Management Act of 2009. The new paleontology-focused legislation includes provisions related to inventory, monitoring, public education, research and collecting permits, curation, and criminal/civil prosecution associated with fossils from designated DOI lands. More information on laws, policies, and authorities governing NPS management of paleontological resources is detailed in Appendix D. Paleontological resource protection training is available for NPS staff through the Geologic Resources Division. GRD is also available to provide support in investigations of paleontological resource theft or vandalism.

As of the date of this publication, an interagency coordination team including representatives from the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), National Park Service (NPS) and U.S. Fish & Wildlife Service (FWS) is in the process of developing Department of Interior (DOI) final regulations for PRPA. Draft DOI regulations were published in the Federal Register in December 2016 and were available for 60 days to allow for public comment. The interagency team has reviewed public comments provided for the draft regulation and have drafted the final regulation. The final regulation has completed surnaming by the DOI Solicitor's Office and each of the four bureau directors. The final regulation has been forwarded for final review by DOI Assistant Secretaries. For more information regarding this act, visit https://www.nps.gov/subjects/fossils/fossil-protection.htm.

2006 National Park Service Management Policies (section 4.8.2.1) state

> *… Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).*
>
> *Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion. Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately*

documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.

The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.

All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins. Areas with potential paleontological resources must also be monitored during construction projects.

Fossils have scientific, aesthetic, cultural, educational, and tourism value, and impacts to any of these values impairs their usefulness. Effective paleontological resource management protects fossil resources by implementing strategies that mitigate, reduce, or eliminate loss of fossilized materials and their relevant data. Because fossils are representatives of adaptation, evolution, and diversity of life through deep time, they have intrinsic scientific values beyond just the physical objects themselves. Their geological and geospatial contexts provide additional critical data concerning paleoenvironmental, paleogeographic, paleoecologic, and a number of other conditions that together allow for a more complete interpretation of the physical and biological history of the earth. Therefore, paleontological resource management must act to protect not only the fossils themselves, but to collect and maintain other contextual data as well.

In general, losses of paleontological resources result from naturally occurring physical processes, by direct or indirect human activities, or by a combination of both. These processes or activities influence the stability and condition of in situ paleontological resources (Santucci and Koch 2003; Santucci et al. 2009). The greatest loss of associated contextual data occurs when fossils are removed from their original geological context without appropriate documentation. Thus, when a fossil weathers and erodes from its surrounding sediments and geologic context, it begins to lose significant ancillary data until, at some point, it becomes more a scientific curiosity than a useful piece of scientific data. A piece of loose fossil “float” can still be of scientific value. However, when a fossil has been completely removed from its original context, such as an unlabeled personal souvenir or a specimen with no provenance information in a collection, it is of very limited scientific utility. Similarly, fossils inadvertently exhumed during roadway construction or a building excavation may result in the loss or impairment of the scientific and educational values associated with those fossils. It is not necessary to list here all of the natural and anthropogenic factors that can lead to the loss of paleontological resources; rather it is sufficient to acknowledge that anything which disturbs native sediment or original bedrock has potential to result in the loss of the paleontological resources that occur there, or the loss of the associated paleontological resource data.

Cave localities are in a distinct class for management due to the close connection with archeological resources and unique issues affecting cave resources. They are also frequently important sources of paleontological resources, as at CHIS. See Santucci et al. (2001) for additional discussion of paleontological resources in cave settings.

Management strategies to address any of these conditions and factors could also incorporate the assistance of qualified specialists to collect and document resources rather than relying solely on staff to accomplish such a large task at CHIS (see also "Management and Monitoring Issues Specific to CHIS" below).

Baseline Paleontology Resource Data Inventories

A baseline inventory of paleontological resources is critical for implementing effective management strategies, as it provides information for decision-making. This inventory report has compiled information on previous paleontological research done in and near CHIS, taxonomic groups that have been reported within CHIS boundaries, and localities that were previously reported. This report can serve as a baseline source of information for future research, inventory reports, monitoring, and paleontological decisions. In turn, the Paleontological Resource Inventory and Monitoring report for the MEDN completed by Tweet et al. (2012) and the references cited within were important baseline paleontological resource data sources for this CHIS-specific report.

Paleontological Resource Monitoring

Paleontological resource monitoring is a significant part of paleontological resource management, and one which usually requires little to implement beyond time and equipment already on hand, such as cameras and GPS units. Monitoring enables the evaluation of the condition and stability of in situ paleontological resources. A monitoring program revolves around periodic site visits to assess conditions compared to a baseline for that site, with the periodicity depending on factors such as site productivity, accessibility, and significance of management issues. For example, a highly productive site which is strongly affected by erosion and unauthorized collection, and which can be easily visited by park staff, would be scheduled for more frequent visits than a less productive or less threatened site. During a field excursion to Santa Rosa Island in June 2019 as part of the creation of this report, park staff introduced site documentation and condition assessments for significant fossil localities using a portable GPS-equipped wireless device with a built-in form.

A monitoring program is generally implemented after an inventory has been prepared for a park and sites of concern have been identified, with additional sites added as necessary. Because each park is different, with different geology and paleontology among other factors, ideally each park which has in situ fossils or significant accumulations of reworked fossils would have its own monitoring protocol to define its monitoring program. Data accumulated via monitoring is used to inform further management decisions. Is the site suitable for interpretation and education? Does the site require stabilization from the elements? Is collection warranted? Is there a need for some form of law enforcement presence?

In the course of this inventory, paleontological localities have been evaluated for factors that could cause potential loss of paleontological resources. Their overall conditions are reported as good, fair, or poor based on the situations found at each individual locality. Risks and conditions that influence the degree of potential loss are categorized as Disturbance, Fragility, Abundance, and Site Access. "Disturbance" evaluates conditions that promote accelerated erosion or mass wasting resulting from human activities. "Fragility" evaluates natural conditions that may influence the degree to which fossil transportation is occurring, such as inherently soft rapidly eroding sediment or mass wasting on steep hillsides. "Abundance" judges both the natural condition and number of specimens actually preserved in the deposits as well as the risk of being easily recognized as a fossil-rich area which could lead to the possibility of unpermitted collecting. "Site Access" assesses the risk of a locality being visited by large numbers of visitors or the potential for easy removal of large quantities of fossils or fossil-bearing sediments as a result of proximity to public use areas or other access (along trails, at roadcuts, at beach or river access points, and so on).

Each of the factors noted above may be mitigated by management actions. Localities exhibiting a significant degree of disturbance may require either active intervention to slow accelerated erosion, periodic collection and documentation of fossil materials, or both. Localities developed on sediments of high fragility naturally erode at a relatively rapid rate and would require frequent visits to document and/or collect exposed fossils in order to prevent or reduce losses. Localities with abundant or rare fossils, or high rates of erosion, may be considered for periodic monitoring in order to assess the stability and condition of the locality and resources, in regard to both natural processes and human-related activities. Localities that are easily accessible by road or trail would benefit from the same management strategies as those with abundant fossils and by occasional unscheduled visits by park staff, documentation of in situ specimens, and/or frequent law enforcement patrols. Further information on paleontological resource monitoring can be found in Santucci and Koch (2003) and Santucci et al. (2009).

Management and Monitoring Issues Specific to CHIS

CHIS does not currently have a paleontological resource specialist on staff. The abundance of fossils and the likelihood of rapid erosion once exposed speak to the need for a more proactive paleontological resource program on the islands. Although paleontological research projects are relatively frequent, they are created to support specific tasks, and thus there is limited flexibility for the people working on these projects to respond to other discoveries. These circumstances are compounded by the logistical issues inherent to working on undeveloped islands. This is not to say that such projects do not have value from a management perspective, only that they are limited in scope. One potential solution is the creation of a programmatic permit or agreement to allow a trusted non-NPS scientist to essentially act as a park paleontological resource specialist, to survey, monitor, follow up on other reports, collect as necessary, and provide recommendations to the park. Such a program need not be limited to one person or institution, either; the quantity of paleontological resources is great enough to keep many researchers busy. Institutions with significant collections from the islands may be interested in participating, such as the SBMNH or LACM. The Mammoth Site of Hot Springs also has a long working relationship with the park, although given the distances involved it would not be logistically feasible for the Mammoth Site to be the primary institutional participant in such a program.

Much of CHIS is regarded as immediately eligible (proposed wilderness) or may be eligible in the future (potential wilderness) for designation as wilderness under the Wilderness Act. Proposed areas include Middle and West Anacapa and almost all of Santa Barbara Island. Areas regarded as potential wilderness include almost all of Santa Rosa Island and almost all of the NPS-owned portion of Santa Cruz Island. San Miguel Island is not eligible because it is owned by the Department of Defense. Although the lands have not yet been formally designated as wilderness, they are treated as though they have been designated. The provisions of the Wilderness Act complicate some aspects of paleontological fieldwork. Establishing camps close to sites or operating from a boat reduce the need for long drives.

NPS Foundation Documents and Resource Stewardship Strategies

Foundation documents and Resource Stewardship Strategies are two types of park planning documents that may contain and reference paleontological resource information. A foundation document is intended to provide basic guidance about a park for planning and management. It briefly describes a given park and its purpose, significance, fundamental resources and values, other importance resources and values, and interpretive themes. Mandates and commitments are also identified, and the state of planning is assessed. Foundation documents may include paleontological information, and are also useful as a preliminary assessment of what park staff know about their paleontological resources, the importance they place on these resources, and the present state of these non-renewable resources. A foundation document for CHIS has been published (NPS 2017).

A Resource Stewardship Strategy (RSS) is a strategic plan intended to help park managers achieve and maintain desired resource conditions over time. It offers specific information on the current state of resources and planning, management priorities, and management goals over various time frames. An RSS is in progress for CHIS and is planned to be completed in calendar year 2020 (K. Convery, pers. obs., February 2020).

Geologic Maps

A geologic map is the fundamental tool for depicting the geology of an area. Geologic maps are two-dimensional representations of the three-dimensional geometry of rock and sediment at or beneath the land surface (Evans 2016). Colors and symbols on geologic maps correspond to geologic map units. The unit symbols consist of an uppercase letter indicating the age and lowercase letters indicating the formation’s name. The American Geosciences Institute website (https://www.americangeosciences.org/environment/publications/mapping) provides more information about geologic maps and their uses. The NPS Geologic Resources Inventory (GRI) has been digitizing existing maps of NPS units and making them available to parks for resource management.

Geologic maps are one of the foundational elements of a paleontological resource management program. Knowing which sedimentary rocks and deposits underlie a park and where they are exposed are essential for understanding the distribution of known or potential paleontological resources. The ideal scale for resource management in the 48 contiguous states is 1:24,000 (maps for areas in Alaska tend to be coarser). All maps digitized by the GRI for CHIS are at 1:24,000 or 1:12,000. It should be noted that the selected bedrock maps of the three large islands were prepared during the 1960s, and so some changes in terminology and the placement of contacts should be expected. Whenever possible, page-sized geologic maps derived from the GRI's files are included in paleontological resource inventory reports for reference, but park staff are encouraged to download the GRI's source files from IRMA. The source files can be explored in much greater detail and incorporated into the park GIS database. Links to the maps digitized by the GRI for CHIS can be found in IRMA at https://irma.nps.gov/Datastore/Reference/Profile/2194552. In addition to a digital GIS geologic map, the GRI program also produces a park-specific report discussing the geologic setting, distinctive geologic features and processes within the park, highlighting geologic issues facing resource managers, and describing the geologic history leading to the present-day landscape of the park. Such a report has not been completed for CHIS at the time of this writing.

Paleontological Potential Maps

Paleontological potential maps have been prepared for CHIS management. The maps show the distribution of geologic units within a park that are known to have yielded fossils within the park (green), have not yielded fossils within the park but are fossiliferous elsewhere (yellow), or have not yielded fossils (red). These maps give a quick indication of areas where fossils may be discovered, which in turn can provide suggestions for areas to survey or monitor, or areas where the discovery of fossils during work that disturbs the ground may be of concern (road work, building construction, etc.).

Paleontological Resource Management Recommendations

The paleontological resource inventory at CHIS has documented an extensive assemblage of paleontological resources, illustrating the scope, significance, and distribution of the fossils from the park. Below are a series of recommendations to take the management and study of these non-renewable paleontological resources into the future.

- CHIS staff should be encouraged to observe exposed rocks and sedimentary deposits for fossil material while conducting their usual duties. To promote this, staff should receive guidance and/or training regarding how to recognize local fossils, especially the most common fossils found at CHIS. When opportunities arise to observe paleontological resources in the field and take part in paleontological field studies with trained paleontologists, staff should take advantage of them, if funding and time permit.
- CHIS should consider field inventories of paleontological resources to more fully document in situ occurrences of fossils and fossiliferous localities, and to evaluate fossiliferous areas for vulnerability to coastal erosion, landslides, and human disturbance, as a step toward a monitoring program. Different methods of surveying may be appropriate for different settings; for example, an exploratory survey in a little-studied area would require more time than a survey focused on known localities or on a particular formation. Regardless of the type of field work, it can be expected that the work will be primarily conducted on foot.
- CHIS staff should photo-document and monitor in situ occurrences of paleontological resources. Fossils and their associated geologic context (surrounding rock or sediment) should be documented, but left in place unless they are subject to imminent degradation. A Geologic Resource Monitoring Manual published by the Geological Society of America and NPS Geologic Resources Division (GRD) includes a chapter on paleontological resource monitoring (Santucci et al. 2009). Santucci and Koch (2003) also present information on paleontological resource monitoring.
- In conjunction with the previous item, it is recommended that a paleontological resource monitoring program be established at CHIS. GRD can offer assistance setting up such a program, and/or holding paleontological resource monitoring and protection training for staff. A request can be submitted through the System for Technical Assistance Requests (STAR) (https://irma.nps.gov/STAR/).
- As discussed under "Management and Monitoring Issues Specific to CHIS", issuing a programmatic permit or agreement for a trusted outside scientist to act in the capacity of a park paleontology specialist may be a way to address the need for proactive paleontological resource management. Active recruitment of paleontological research scientists should be used as a management strategy in general, because these outside scientists will provide experienced eyes on the ground regarding the condition of the resource, although they cannot be expected to greatly exceed their intended research projects (e.g., someone working on Santa Rosa Island may be able to visit another site on that island during their work, but not a site on Santa Barbara Island).

- The park may fund and recruit paleontology interns as a cost-effective means of enabling some level of paleontological resource support. The Geoscientists-in-the-Parks Program is an established program for recruitment of geology and paleontology interns. Other options include partnering with nearby colleges such as Santa Barbara City College or California State University Channel Islands.
- The Channel Islands Naturalist Corps may represent another pool of recruits for paleontological resource work, particularly for projects intended to be carried out over a longer period than a typical 12-week internship, such as site stewardship. The NPS Paleontology Program can provide training for members of the Naturalist Corps or other volunteers interested in supporting paleontological resource stewardship.
- Coordinating surveys and monitoring for multiple resource categories may be an efficient way of deploying resources and staff, if such coordination if feasible. In particular, any proposed survey of paleontological resources also offers opportunities to discover and assess cultural resources, and vice-versa. Basic procedures for surveying and monitoring these resources are similar. Monitoring paleontological resources also offers a natural venue for assessing caves, shorelines, and geological hazards.
- Because of the overlap of natural and cultural resources, and the need for individual staff to cover duties in multiple areas, both Natural Resources and Cultural Resources have played roles in paleontological resource management at CHIS. Although some of this overlap is unavoidable and natural, going forward it may be useful to firmly assign lead responsibility to one of the two. Communication with Interpretation is also important, so that everyone is on the same page.
- If authorization can be secured, the use of a drone (unmanned aerial vehicle/UAV) offers a way to survey steep terrain for fossil occurrences. In addition to surveying, video records produced by a drone could be compiled and archived as a means to monitor sites which are otherwise poorly accessible. Drones could be coupled with boat-based surveys and operated on days of inclement weather. Another potential use is surveying areas occupied by pinnipeds.
- Remote cameras may be suitable at some paleontological localities for site monitoring and/or public education, similar to the park's current use of remote cameras for webcams.
- Continued efforts should be made to document and understand the stratigraphy and chronology of the late Quaternary on the islands, following such recent works as Pigati et al. (2017) and Muhs and Groves (2018). A well-developed stratigraphic and chronologic framework puts the paleontologic resources in the proper spatial and temporal context, which greatly assists current and future researchers working to understand faunal changes through time. It also illustrates the geologic processes that resulted in past and present environmental conditions, and provides examples for future management at CHIS and similar ecosystems.
- Periodic field surveys for mammoth specimens have occurred in the past, but there is not an active permit. Such surveying should be resumed, with increased recording of geologic data to better place specimens in stratigraphic, chronologic, and environmental contexts.

- Fossils of several taxa are present in great numbers, such as *Helminthoglypta ayresiana* shells (Johnson 1971) and *Peromyscus nesodytes* bones. These large sample sizes could be ideal for projects requiring robust quantitative data.
- A number of caves have been documented on CHIS, including more than 380 sea caves. Some of the park's caves are already known as significant sources of fossils, but many others are unstudied. These unstudied caves should be inventoried for fossils.
- High rates of coastal erosion and frequent landslides are significant threats to paleontological resources at CHIS. Mammoth fossils on CHIS islands can be exposed on cliffs and lost to the sea in a single winter (Santucci and Koch 2003). Regular inspection of vulnerable areas, with periodic salvage (as described in Guthrie 2005), can be employed to deal with these issues.
- Fossil theft and vandalism can threaten paleontological resources, and any methods and strategies to minimize these activities should be considered by staff. Any occurrence of paleontological resource theft or vandalism should be investigated by a law enforcement ranger. When possible, the incident should be fully documented and the information submitted for inclusion in the annual law enforcement statistics. There is some anecdotal evidence of illegal collection at the islands, possibly in part by commercial sea urchin divers on surface intervals (D. Morris, pers. comm., June and July 2019). Lulis Cuevas, who was raised on Santa Rosa Island and was an NPS law enforcement ranger before retirement, may have some knowledge about fossil theft on the islands.
- A study of the human dimensions surrounding CHIS paleontology may be helpful for planning ways to promote and interpret the park's fossil resources while also protecting them from adverse human impacts. It has been suggested that publicizing monitoring efforts may be useful because it would show well-meaning collectors that the park does care about fossils, and a social study may be a way to test this suggestion.
- As discussed in the text, the islands of CHIS were much larger only a few thousand years ago, when sea level was lower. Therefore, the submerged areas around the islands should also have late Pleistocene terrestrial fossils as well as early archeological sites. Archeological investigations of submerged areas within and near CHIS boundaries may uncover paleontological resources, which should be documented like those found on land. Artifacts and bones from drowned sites are known to wash up on Santa Rosa Island (Orr 1956b).
- Fossils found in a cultural context should be documented like other fossils, but will also require the input of an archeologist or a cultural resource specialist. Any fossil which has a cultural context may be culturally sensitive as well (e.g., subject to NAGPRA) and should be regarded as such until otherwise established. The GRD can coordinate additional documentation/research of such material.
- Infrastructure developments or archeological excavations should consider scheduling site monitoring by a trained paleontologist in order to document and protect fossil resources. Preconstruction planning and environmental screening in association with the National Environmental Policy Act (NEPA) should be incorporated into all ground disturbing activities which may potentially impact in situ fossils at CHIS.

- CHIS staff have expressed interest in additional paleontology-focused educational and interpretive materials, including CHIS-specific Junior Paleontologist content and a fact sheet similar to Springer et al. (2018) for Tule Springs Fossil Beds National Monument. Information from this report could be adapted for either purpose.
- Researchers should be encouraged to present on their research for park staff and the public.
- Additional ways to bring the park's paleontology to the public include physical 3D replicas of specimens and photogrammetric models which can be posted online. The Western Science Center has already made 3D models of a CHIS pygmy mammoth jaw and tooth from specimens at the Santa Barbara Museum of Natural History. GRD has experience making photogrammetric models and can provide assistance.
- Contact the GRD for technical assistance with paleontological resource management issues.

If fossil specimens are found by CHIS staff, it is recommended they follow the steps outlined below to ensure proper paleontological resource management. Full recording of geological context, supplemented by a good photographic record, is essential.

- Photo-document the specimen without moving it from its location, if it is loose. Include a common item, such as a coin, pen, or pencil, for scale if a ruler or scale bar is not available.
- If GPS technology is available, record the location of the specimen. A dedicated GPS unit is not necessary; cell phones can produce comparable results in many situations. If this is not possible, document the location using such landmarks as are available. Making one or more sketches of the location and the position of the fossil(s) is strongly recommended in this situation. If possible, revisit the site when a GPS unit is available.
- Record associated data, such as rock type, general description of the fossil, type of fossil if identifiable, general location in CHIS, sketch of the fossil, position within the outcrop or sediment layer (or if it is loose on the ground), any associated fossils, and any other additional information.
- Do not remove the fossil unless it is loose in a heavily trafficked area, such as a public trail, and is at risk of being taken or destroyed. If the fossil is removed, be sure to wrap in soft material, such as toilet paper, and place in a labeled plastic bag with associated notes.
- If fossil resources are found, alert staff at CHIS to allow for proper documentation and potential collection. Prompt and careful action is needed for significant vertebrate finds because they are often very fragile.

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Appendix A: Paleontological Species Lists

The following tables (Appendix Tables A-1 through A-6) document the fossil species found at CHIS in stratigraphic context, as reported in the literature, in museum collections, and through personal observations. The rows are organized systematically, placing taxa of the same broad groups together, with gray rows providing summaries of each group. Except for categories of taxa represented by only Quaternary fossils, the columns are organized by formation, which are presented in ascending order (oldest to youngest) left to right. The columns also include the taxon (first column) and references (last column; included in "Literature Cited" above). For convenience, and to coordinate with the GRI maps, the pre-Pleistocene formations of San Miguel Island, Santa Rosa Island, and Santa Cruz Island are divided as they are on the GRI maps, which in turn are largely based on the 1969 maps. The authors attempted to fit reports using different nomenclature to the GRI framework. Taxa did not necessarily persist through the entire unit in which they are cited; they may have appeared during its deposition, went extinct or were locally extirpated before the end, or both. This is particularly worth noting for Quaternary records, which are lumped for each island (except for the Potato Harbor Formation and Middle Anchorage Alluvium of Santa Cruz Island). The great majority of reported Quaternary fossils of CHIS probably represent only a small fraction of the 2.58 million years of the Quaternary Period, yet great changes in sea level and climate produced noticeably different assemblages over that relatively short time frame. Holocene records up to the arrival of Europeans are included. Although Holocene materials are sometimes dismissed as "subfossil", a complete record of the past necessitates their inclusion, and the taxa and the references discussing them are of interest for management, education, and other purposes.

If a taxon is present in a given formation at a locality that can be placed within CHIS, that cell is marked with a "Y". If there is some question about the presence of a taxon in a specific formation, the cell is marked with a "?". If a taxon is known to be present but the stratigraphic unit is unclear (for example, if a reference used an obsolete stratigraphic name or predates the division of a formation), the record is marked "U". Taxa known to have been reworked are denoted with an "RO" (reworked out) for the source unit (if known, which is not always the case; sometimes only the general age is known) and "RI" (reworked in) for the unit into which they have been redeposited. This does not include modern float; the reworked fossil has to have been re-incorporated into another geologic unit. Taxa named for a specimen collected on a given island are underlined.

Taxonomy is always in flux, and each author is liable to view the best assignments of taxa differently than others. Although we have attempted to account for changes in usage over time, and for different authors identifying the same fossils as different taxa, it is inevitable that some have been missed. For convenience, the most recent usage of a given name in the CHIS literature was favored, with minor typographical errors corrected (e.g., "*Diapatra*" for *Diopatra*, or "*pygmacea*" for *pygmaea*). A list of taxonomic revisions is provided after the tables. Because the islands share the same pool of taxa, the list applies to all of the islands. In addition, two types of changes have been applied that may not have appeared in the CHIS literature, but which are in accordance with the modern rules of nomenclature: hyphens have been removed, and varieties (var.) of non-botanical taxa have been reported as subspecies instead.

The publication record of mammoths on San Miguel Island and Santa Rosa Island is lengthy, with the fossils frequently mentioned in passing, and CHIS mammoths are dealt with extensively in the text. Therefore, the "Reference" column for these taxa are limited to a few references, sometimes only a single recent publication.

The taxa reported by Voy (1890–1893a, 1890–1893b) and Yates (1902–1905) have been omitted because they are essentially obsolete (almost none of them were reported by later researchers, illustrating that they reflect an early stage in Californian paleontology) and have little stratigraphic information attached to them. They are mostly of historical interest.

San Miguel Island Records

The San Miguel Island records have been divided into five tables: Appendix Table A-1-a for fossil plants, Appendix Table A-1-b for fossil invertebrates, Appendix Table A-1-c for fossil vertebrates, Appendix Table A-1-d for ichnofossils, and Appendix Table A-1-e for other fossils.

Daniel Guthrie published several lists of San Miguel Island avifauna (Guthrie 1980, 1992, 1993, 1998, 2005; Collins et al. 2018a). Only the most recent list was used for the table.

Beachrock on San Miguel Island includes carbonate grains. Almost all of these grains are sand-sized skeletal fragments, primarily from mollusks and forams (Johnson 1969).

A report in Guthrie (1980) of Holocene *Desmodus stocki* on San Miguel Island was retracted in Guthrie (1993).

Abbreviations for San Miguel Island stratigraphic units, used throughout Appendix A-1 tables:
Q = Quaternary deposits
Tmsh = Monterey Formation, shale member
Tmbt = Beechers Bay Formation
Tsm = San Miguel Volcanics
Tr = Vaqueros/Rincon Formation
Tsp = South Point Formation
Tpc = Undifferentiated Pozo–Cañada Formation
Kj = Jalama Formation

For each table, only those formations with records are included. Therefore, the tables for fossil plants and fossil vertebrates represent only the Quaternary (Appendix tables A-1-a and A-1-c); the fossil invertebrates table includes all but Tsm (San Miguel Volcanics) (Appendix Table A-1-b); the ichnofossils table includes only Kj (Jalama Formation), Tpc (Undifferentiated Pozo–Cañada Formation), Tsp (South Point Formation), and Q (Quaternary deposits) (Appendix Table A-1-d); and the other fossils table includes all but Tmbt (Beechers Bay Formation) (Appendix Table A-1-e).

Appendix Table A-1-a. Quaternary plant taxa reported from San Miguel Island; Anderson et al. records are of late Holocene age.

Group	Taxon	References
Pinophyta (conifers)	*Cupressus* sp.	Johnson 1981
	Pinus muricata	West and Erlandson 1994
	Pinus radiata	Johnson 1977
	Pinus pollen	West and Erlandson 1994, Anderson et al. unpublished data
Magnoliophyta (flowering plants)	*Alnus* pollen	Anderson et al. unpublished data
	Ambrosia pollen	Anderson et al. unpublished data
	Artemisia pollen	Anderson et al. unpublished data
	Baccharis pollen	Anderson et al. unpublished data
	Betula pollen	Anderson et al. unpublished data
	Ceanothus pollen	Anderson et al. unpublished data
	Chaenactis pollen	Anderson et al. unpublished data
	Cirsium pollen	Anderson et al. unpublished data
	Eriophyllum pollen	Anderson et al. unpublished data
	Erodium pollen	Anderson et al. unpublished data
	Helianthus pollen	Anderson et al. unpublished data
	Phyllospadix spp.	Ainis et al. 2011
	Plantago pollen	Anderson et al. unpublished data
	Primula pollen	Anderson et al. unpublished data
	Prunus pollen	Anderson et al. unpublished data
	Quercus pollen	Anderson et al. unpublished data
	Rhus integrifolia? (caliche structures)	Cockerell 1938b
	Rhus sp.?	Johnson 1977
	Ribes sp.	Johnson 1977
	Solidago pollen	Anderson et al. unpublished data
	Amaranthaceae pollen	Anderson et al. unpublished data
	Apiaceae pollen	Anderson et al. unpublished data

Appendix Table A-1-a (continued). Quaternary plant taxa reported from San Miguel Island; Anderson et al. records are of late Holocene age.

Group	Taxon	References
Magnoliophyta (flowering plants) (continued)	Asteraceae (formerly Compositae) pollen	West and Erlandson 1994, Anderson et al. unpublished data
	Lactuceae pollen	Anderson et al. unpublished data
	Lamiaceae pollen	Anderson et al. unpublished data
	Poaceae pollen	Anderson et al. unpublished data
	Rosaceae pollen	West and Erlandson 1994
Unclassified plant remains	Charcoal	Johnson 1977, Scott et al. 2010, Ainis et al. 2011, Pinter et al. 2011, Pigati et al. 2017
	Rhizoconcretions	Bremner 1933, Johnson 1977
	Twigs	Erlandson et al. 1996, 2011

Appendix Table A-1-b. Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Porifera (sponges)	Porifera undetermined	–	–	–	–	–	–	Y	Ainis et al. 2011
Cnidaria: Anthozoa: Scleractinia (stony corals)	*Balanophyllia elegans*	–	–	–	–	–	–	Y	Muhs et al. 2014
Bryozoa (moss animals)	Bryozoa undetermined	–	–	–	Y	–	–	–	Bremner 1933
Brachiopoda (lamp shells)	*Hemithyris* sp.	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
Mollusca	**Mollusca overall**	**Y**	**Y?**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
	Mollusca undetermined	–	–	Y	–	–	–	Y	Bremner 1933, Weaver and Doerner 1969a, Kies 1982, Erlandson et al. 2011
Mollusca: Polyplacophora (chitons)	*Cryptochiton stelleri*	–	–	–	–	–	–	Y	Erlandson et al. 1996, 2011, Ainis et al. 2011, Muhs et al. 2014
	Katharina tunicata	–	–	–	–	–	–	Y	Erlandson et al. 2011

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Mollusca: Polyplacophora (chitons) (continued)	Polyplacophora undetermined	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011, Muhs et al. 2014
Mollusca: Bivalvia (clams, oysters, etc.)	**Bivalvia overall**	**Y**	**Y?**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
	Acutostrea? *miguelensis*	–	–	–	Y	–	–	–	Hertlein 1928, Loel and Corey 1932, Moore 1987
	Amussiopecten vanvlecki	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
	Arca n. sp.?	–	–	–	Y	–	–	–	Bremner 1933
	Avonia peruviana	–	–	–	–	–	–	Y	Ainis et al. 2011
	Chione sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Chlamys hastata	–	–	–	–	–	–	Y	Muhs et al. 2014
	Crassadoma gigantea	–	–	–	–	–	–	Y	Johnson 1972, Muhs et al. 2014
	Crassostrea titan subtitan	–	–	–	Y	Y	–	–	Loel and Corey 1932, Weaver and Doerner 1969b
	Cumingia californica	–	–	–	–	–	–	Y	Muhs et al. 2014
	Cumingia sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Epilucina californica	–	–	–	–	–	–	Y	Cockerell 1938c, Johnson 1972, Muhs et al. 2014
	Glans carpenteri	–	–	–	–	–	–	Y	Johnson 1972, Muhs et al. 2014
	Glans sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Glycymeris sp.	–	–	–	–	–	–	Y	Johnson 1972, Muhs et al. 2014
	Inoceramus sp.	Y	–	–	–	–	–	–	Bartling and Abbott 1983
	Lyropecten crassicardo	–	–	–	–	Y	Y	–	Weaver and Doerner 1969b, Smith 1991
	Lyropecten miguelensis	–	–	–	Y	–	–	–	Arnold 1906, Hertlein 1928, Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b, Smith 1991
	Lyropecten pretiosus	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b, Smith 1991

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Lyropecten* sp.	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
	Macoma nasuta	–	–	–	–	–	–	Y	Johnson 1972
	Macoma secta	–	–	–	–	–	–	Y	Johnson 1972
	Macoma sespeenesis	–	–	–	Y	–	–	–	Loel and Corey 1932
	Mytilus californianus	–	–	–	–	–	–	Y	Johnson 1972, Erlandson et al. 1996, 2011, Ainis et al. 2011, Muhs et al. 2014
	Mytilus expansus	–	–	–	Y	–	–	–	Loel and Corey 1932
	Mytilus sp.	–	–	–	–	–	–	Y	Johnson 1977, Muhs et al. 2014
	Nutricola tantilla	–	–	–	–	–	–	Y	Johnson 1972, Muhs et al. 2014
	Ostrea eldridgei	–	–	–	Y	–	–	–	Loel and Corey 1932
	Ostrea vespertina	–	–	–	Y	–	–	–	Bremner 1933
	Ostrea vespertina loeli	–	–	–	Y	–	–	–	Loel and Corey 1932
	Ostrea sp.	–	–	–	–	Y	–	–	Bremner 1933
	Panope cf. *P. generosa*	–	–	–	Y	–	–	–	Loel and Corey 1932
	Pecten crassicardo	–	–	–	–	Y	–	–	Bremner 1933
	Pecten hertleini	–	–	–	Y	–	–	–	Loel and Corey 1932
	Pecten sespeensis	–	–	–	Y	–	–	–	Loel and Corey 1932
	Pecten cf. *P. andersoni*	–	–	–	–	Y	–	–	Bremner 1933
	Pecten cf. *P. peckhami*	–	–	–	–	–	Y	–	Bremner 1933
	Pinna stocktoni	–	–	–	Y	–	–	–	Loel and Corey 1932
	Protothaca sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Psephidia cf. *lordi*	–	–	–	–	–	–	Y	Cockerell 1938c
	Septifer bifurcatus	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011, Muhs et al. 2014
	Solen sp.	–	Y?	–	–	–	–	–	Bremner 1933 (horizon questionable)
	Spisula catilliformis	–	–	–	Y	–	–	–	Bremner 1933
	Spondylus perrini	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Spondylus* cf. *S. perrini*	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
	Tellina carpenteri	–	–	–	–	–	–	Y	Johnson 1972
	Tivela inezana	–	–	–	Y	–	–	–	Loel and Corey 1932
	Tivela? cf. *T. inezana*	–	–	–	Y	–	–	–	Bremner 1933
	Undetermined clam	–	–	Y	–	–	–	–	Kies 1982
	Undetermined oyster	–	–	Y	Y	–	–	–	Hertlein 1928, Bremner 1933
	Pholadidae undetermined	–	–	–	–	–	–	Y	Erlandson et al. 2011
	Veneridae undetermined	–	–	–	–	–	–	Y	Ainis et al. 2011
Mollusca: Gastropoda (snails)	**Gastropoda overall**	**–**	**–**	**Y**	**Y**	**–**	**–**	**Y**	**–**
	Acanthina sp.	–	–	–	–	–	–	Y	Johnson 1972
	Acanthinucella paucilirata	–	–	–	–	–	–	Y	Muhs et al. 2014
	Acmaea digitalis	–	–	–	–	–	–	Y	Cockerell 1938c
	Acmaea mitra	–	–	–	–	–	–	Y	Johnson 1972, Muhs et al. 2014
	Acteocina culcitella	–	–	–	–	–	–	Y	Johnson 1972
	Alia carinata	–	–	–	–	–	–	Y	Muhs et al. 2014
	Amphissa versicolor	–	–	–	–	–	–	Y	Muhs et al. 2014
	Amphissa sp.	–	–	–	–	–	–	Y	Johnson 1972
	Antisabia panamensis	–	–	–	–	–	–	Y	Muhs et al. 2014
	Barleeia haliotiphila	–	–	–	–	–	–	Y	Muhs et al. 2014
	Bittium sp.	–	–	–	–	–	–	Y	Johnson 1972, Muhs et al. 2014
	Calicantharus fortis	–	–	–	–	–	–	Y	Cockerell 1938c, Johnson 1972, Muhs et al. 2014
	Californiconus californicus	–	–	–	–	–	–	Y	Muhs et al. 2014
	Callianax biplicata	–	–	–	–	–	–	Y	Cockerell 1938c, Johnson 1972, Erlandson et al. 2011, Muhs et al. 2014
	Calliostoma ligatum	–	–	–	–	–	–	Y	Muhs et al. 2014
	Ceratostoma cf. *C. nuttalli*	–	–	–	–	–	–	Y	Muhs et al. 2014

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Cerithiopsis* sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Chlorostoma brunnea	–	–	–	–	–	–	Y	Ainis et al. 2011, Muhs et al. 2014
	Chlorostoma funebralis	–	–	–	–	–	–	Y	Johnson 1972, Erlandson et al. 1996, 2011, Ainis et al. 2011, Muhs et al. 2014
	Chlorostoma spp.	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011, Muhs et al. 2014
	Conus sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Crassispira sp.	–	–	–	–	–	–	Y	Johnson 1972
	Crepidula adunca	–	–	–	–	–	–	Y	Cockerell 1938c
	Crepidula onyx	–	–	–	–	–	–	Y	Cockerell 1938c
	Crepidula princeps	–	–	–	–	–	–	Y	Johnson 1972
	Crepidula cf. *C. aculeata*	–	–	–	–	–	–	Y	Johnson 1972
	Crepidula cf. *C. norrisiarum*	–	–	–	–	–	–	Y	Johnson 1972
	Crepidula cf. *C. praerupta*	–	–	–	Y	–	–	–	Loel and Corey 1932
	Crepidula sp.	–	–	–	–	–	–	Y	Johnson 1972, Erlandson et al. 2011, Muhs et al. 2014
	Crepidula spp.	–	–	–	–	–	–	Y	Erlandson et al. 2011
	Diodora aspera	–	–	–	–	–	–	Y	Johnson 1972, Muhs et al. 2014
	Discurria insessa	–	–	–	–	–	–	Y	Muhs et al. 2014
	Elaeocyma empyrosia	–	–	–	–	–	–	Y	Johnson 1972
	Epitonium tinctum	–	–	–	–	–	–	Y	Muhs et al. 2014
	Epitonium sp.	–	–	–	–	–	–	Y	Johnson 1972
	<u>*Fissurella rixfordi*</u>	–	–	–	Y	–	–	–	Hertlein 1928, Loel and Corey 1932
	Fissurella volcano	–	–	–	–	–	–	Y	Muhs et al. 2014
	Garnotia adunca	–	–	–	–	–	–	Y	Muhs et al. 2014
	Haliotis cracherodii	–	–	–	–	–	–	Y	Erlandson et al. 1996, 2011, Ainis et al. 2011, Muhs et al. 2014

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Haliotis rufescens*	–	–	–	–	–	–	Y	Johnson 1977, Erlandson et al. 1996, 2011, Ainis et al. 2011, Muhs et al. 2014
	Haliotis sp.	–	–	–	–	–	–	Y	Johnson 1977, Muhs et al. 2014
	Haliotis spp.	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011
	Harfordia harfordii	–	–	–	–	–	–	Y	Muhs et al. 2014
	Helminthoglypta ayresiana	–	–	–	–	–	–	Y	Cockerell 1937, 1938a, Johnson 1971, Guthrie 1993
	Hipponix tumens	–	–	–	–	–	–	Y	Cockerell 1938c, Muhs et al. 2014
	Homalopoma luridum	–	–	–	–	–	–	Y	Johnson 1972
	Lacuna cf. *L. unifasciata*	–	–	–	–	–	–	Y	Johnson 1972
	Lirobittium attenuatum	–	–	–	–	–	–	Y	Johnson 1972
	Lirularia optabilis	–	–	–	–	–	–	Y	Johnson 1972
	Littorina scutulata	–	–	–	–	–	–	Y	Muhs et al. 2014
	Littorina cf. *L. scutulata*	–	–	–	–	–	–	Y	Johnson 1972
	Lottia gigantea	–	–	–	–	–	–	Y	Ainis et al. 2011
	Lottia limatula	–	–	–	–	–	–	Y	Ainis et al. 2011
	Lottia pelta	–	–	–	–	–	–	Y	Cockerell 1938c
	Lottia cf. *L. edmitchelli*	–	–	–	–	–	–	Y	Johnson 1972
	Lottia cf. *L. limatula*	–	–	–	–	–	–	Y	Johnson 1972
	Lottia cf. *L. scabra*	–	–	–	–	–	–	Y	Johnson 1972
	Lottia cf. *L. scabra* (extreme variant)	–	–	–	–	–	–	Y	Cockerell 1938c
	Lottia spp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Mangelia nitens	–	–	–	–	–	–	Y	Johnson 1972
	Margarites lacunata	–	–	–	–	–	–	Y	Johnson 1972
	Mitra idae	–	–	–	–	–	–	Y	Muhs et al. 2014
	Mitrella gausapata	–	–	–	–	–	–	Y	Cockerell 1938c

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Mitrella tuberosa*	–	–	–	–	–	–	Y	Muhs et al. 2014
	Nassarius churchi	–	–	–	Y	–	–	–	Loel and Corey 1932
	Nassarius mendicus	–	–	–	–	–	–	Y	Johnson 1972
	Natica cf. *N. reclusiana*	–	–	–	Y	–	–	–	Bremner 1933
	Neobernaya spadicea	–	–	–	–	–	–	Y	Muhs et al. 2014
	Neostylidium eschrichtii montereyense	–	–	–	–	–	–	Y	Johnson 1972
	Ocenebra cf. *O. tenuisculpta*	–	–	–	–	–	–	Y	Johnson 1972
	Ocenebra?	–	–	–	–	–	–	Y	Johnson 1972
	Ocinebrina cf. *O. lurida*	–	–	–	–	–	–	Y	Muhs et al. 2014
	Odostomia sp.	–	–	–	–	–	–	Y	Johnson 1972
	Olivella spp.	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011
	Polinices recluzianus andersoni	–	–	–	Y	–	–	–	Loel and Corey 1932
	Pomaulax gibberosa	–	–	–	–	–	–	Y	Muhs et al. 2014
	Purpura topangensis n. var.?	–	–	–	Y	–	–	–	Loel and Corey 1932
	Pusula californiana	–	–	–	–	–	–	Y	Muhs et al. 2014
	Rapana imperialis	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b
	Rapana vaquerosensis	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b
	Serpulorbis sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Serpulorbis spp.	–	–	–	–	–	–	Y	Erlandson et al. 2011
	Thylacodes squamigerus	–	–	–	–	–	–	Y	Johnson 1972, Ainis et al. 2011, Muhs et al. 2014
	Trophonopsis? sp.	–	–	–	–	–	–	Y	Johnson 1972
	Trophosycon ocoyana	–	–	–	Y	–	–	–	Loel and Corey 1932
	Turritella inezana	–	–	–	Y	–	–	–	Hertlein 1928

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Turritella inezana* supervariant	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b
	Turritella ocoyana	–	–	–	Y	–	–	–	Hertlein 1928, Bremner 1933, Weaver and Doerner 1969b
	Turritella ocoyana bosei	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b
	Turritella ocoyana supervariant	–	–	–	Y	–	–	–	Loel and Corey 1932
	Turritella temblorensis	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b
	Turritella temblorensis tritschi	–	–	–	Y	–	–	–	Loel and Corey 1932, Bremner 1933, Weaver and Doerner 1969b
	Turritella sp. cf. *T. ocoyana*	–	–	–	Y	–	–	–	Hertlein 1928
	Acmaeidae undetermined	–	–	–	–	–	–	Y	Johnson 1972, Erlandson et al. 2011
	Gastropoda undetermined (minute)	–	–	–	–	–	–	Y	Johnson 1972
	Gastropoda undetermined	–	–	Y	–	–	–	Y	Kies 1982, Ainis et al. 2011, Erlandson et al. 2011
Arthropoda	**Arthropoda overall**	**–**	**–**	**Y**	**Y**	**–**	**–**	**Y**	**–**
Arthropoda: Crustacea: Cirripedia (barnacles)	*Balanus* sp.	–	–	–	Y	–	–	Y	Loel and Corey 1932, Bremner 1933, Johnson 1977, Erlandson et al. 2011, Muhs et al. 2014
	Balanus spp.	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011
	Pollicipes polymerus	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011
	Cirripedia undetermined	–	–	–	–	–	–	Y	Muhs et al. 2014
Arthropoda: Crustacea: Decapoda: Brachyura (crabs)	Undetermined crab	–	–	Y	–	–	–	Y	Kies 1982, Ainis et al. 2011, Erlandson et al. 2011
Echinodermata: Echinoidea (sea urchins)	**Echinoidea overall**	**–**	**–**	**–**	**Y**	**–**	**–**	**Y**	**–**
	Dendraster sp.	–	–	–	–	–	–	Y	Ainis et al. 2011

Appendix Table A-1-b (continued). Fossil invertebrate taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tmbt	Tmsh	Q	References
Echinodermata: Echinoidea (sea urchins) (continued)	*Echinarachnius vaquerosensis*	–	–	–	Y	–	–	–	Loel and Corey 1932
	Echinarachnius cf. *S. vaquerosensis*	–	–	–	Y	–	–	–	Bremner 1933
	Eucidaris sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Kewia fairbanksi n. var.?	–	–	–	Y	–	–	–	Loel and Corey 1932
	Kewia fairbanksi cf. *K. santanensis*	–	–	–	Y	–	–	–	Bremner 1933, Grant and Hertlein 1938, Weaver and Doerner 1969b
	Strongylocentrotus sp.	–	–	–	–	–	–	Y	Muhs et al. 2014
	Strongylocentrotus spp.	–	–	–	–	–	–	Y	Ainis et al. 2011, Erlandson et al. 2011
Other invertebrates	Undetermined invertebrates	–	–	Y	–	–	–	Y	Bremner 1933, Kies 1982

Appendix Table A-1-c. Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Vertebrata	Undetermined fish	Ainis et al. 2011
	Vertebrata undetermined	Ainis et al. 2011
Chondrichthyes (sharks, rays, etc.)	*Squatina californica*	Rick et al. 2001
	Triakidae undetermined	Rick et al. 2001
	Elasmobranchii undetermined	Bremner 1933, Rick et al. 2001
Actinopterygii (ray-finned fish)	*Damalichthys vacca*	Rick et al. 2001
	Ophiodon elongatus	Rick et al. 2001
	Scorpaenichthys marmoratus	Rick et al. 2001
	Sebastes spp.	Rick et al. 2001
	Semicossyphus pulcher	Rick et al. 2001
	Atherinidae undetermined	Rick et al. 2001
	Clinidae undetermined	Rick et al. 2001

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Actinopterygii (ray-finned fish) (continued)	Clupeidae undetermined	Rick et al. 2001
	Cottidae undetermined	Rick et al. 2001
	Embiotocidae undetermined	Rick et al. 2001
	Engraulidae? undetermined	Rick et al. 2001
	Hexagrammidae undetermined	Rick et al. 2001
	Labridae undetermined	Rick et al. 2001
	Pleuronectiformes undetermined	Rick et al. 2001
	Scorpaenidae undetermined	Rick et al. 2001
	Stichaeidae undetermined	Rick et al. 2001
	Teleostei undetermined	Rick et al. 2001
Amphibia: Anura (frogs)	cf. *Pseudacris*	Mead et al. 2018
Reptilia: Lacertilia (lizards)	*Elgaria multicarinata*	Guthrie 1993, 2005, Ainis et al. 2011
	Sceloporus occidentalis becki?	Ainis et al. 2011
	Lacertilia undetermined	Ainis et al. 2011
Reptilia: Serpentes (snakes)	*Crotalus viridis*	Guthrie 1993, 1998
	Pituophis melanoleucus	Guthrie 1993
Aves	Aves undetermined	Ainis et al. 2011, Collins et al. 2018a
Aves: Anseriformes (ducks and geese)	*Anas acuta*	Collins et al. 2018a
	Anas crecca	Collins et al. 2018a
	Anser albifrons	Collins et al. 2018a
	Anser caerulescens	Collins et al. 2018a
	Anser rossi	Collins et al. 2018a
	Branta bernicla	Collins et al. 2018a
	Branta canadensis	Collins et al. 2018a
	Branta hutchinsii	Collins et al. 2018a
	Chendytes lawi	Jones et al. 2008, Collins et al. 2018a

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Aves: Anseriformes (ducks and geese) (continued)	*Mareca americana*	Collins et al. 2018a
	Melanitta fusca	Collins et al. 2018a
	Melanitta perspicillata	Collins et al. 2018a
	Mergus serrator	Collins et al. 2018a
	Spatula clypeata	Collins et al. 2018a
Aves: Gaviiformes (loons)	*Gavia immer*	Collins et al. 2018a
	Gavia pacifica	Collins et al. 2018a
	Gavia stellata	Collins et al. 2018a
Aves: Podicipediformes (grebes)	*Aechmophorus occidentalis*	Collins et al. 2018a
	Podiceps auritus	Collins et al. 2018a
	Podiceps grisegena	Collins et al. 2018a
	Podiceps nigricollis	Collins et al. 2018a
	Podilymbus podiceps	Collins et al. 2018a
Aves: Procellariiformes (petrels)	*Ardenna creatopus*	Collins et al. 2018a
	Ardenna grisea	Collins et al. 2018a
	Ardenna tenuirostris	Collins et al. 2018a
	cf. *Ardenna bulleri*	Collins et al. 2018a
	Fulmarus glacialis	Collins et al. 2018a
	Oceanodroma furcata	Collins et al. 2018a
	Oceanodroma homochroa	Collins et al. 2018a
	Oceanodroma leucorhoa	Collins et al. 2018a
	Oceanodroma melania	Collins et al. 2018a
	Phoebastria albatrus	Collins et al. 2018a
	cf. *Phoebastria nigripes*	Collins et al. 2018a
	Puffinus opisthomelas	Collins et al. 2018a

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Aves: Suliformes (gannets and cormorants)	*Morus reyanus*	Collins et al. 2018a
	Phalacrocorax auritus	Collins et al. 2018a
	Phalacrocorax pelagicus	Collins et al. 2018a
	Phalacrocorax penicillatus	Collins et al. 2018a
	Phalacrocorax spp.	Collins et al. 2018a
Aves: Pelecaniformes (pelicans, herons, etc.)	*Ardea herodias*	Collins et al. 2018a
	Pelecanus occidentalis	Collins et al. 2018a
	Plegadis chihi	Collins et al. 2018a
Aves: Charadriiformes (gulls, waders, etc.)	*Actitis macularius*	Collins et al. 2018a
	cf. *Aethia psittacula*	Collins et al. 2018a
	Arenaria macularius	Collins et al. 2018a
	Arenaria melanocephala	Collins et al. 2018a
	Brachyramphus marmoratus	Collins et al. 2018a
	Calidris alba	Collins et al. 2018a
	Calidris canutus	Collins et al. 2018a
	cf. *Calidris mauri*	Collins et al. 2018a
	cf. *Calidris melanotos*	Collins et al. 2018a
	Cepphus columba	Collins et al. 2018a
	Cerorhinca monocerata	Collins et al. 2018a
	Charadrius semipalmatus	Collins et al. 2018a
	Charadrius vociferous	Collins et al. 2018a
	cf. *Charadrius nivosus*	Collins et al. 2018a
	Chroicocephalus philadelphius	Collins et al. 2018a
	Fratercula cirrhata	Collins et al. 2018a
	Fratercula dowi	Guthrie et al. 1999, Collins et al. 2018a
	Haematopus bachmani	Collins et al. 2018a

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Aves: Charadriiformes (gulls, waders, etc.) (continued)	*Larus californicus*	Collins et al. 2018a
	Larus delawarensis	Collins et al. 2018a
	Larus heermanni	Collins et al. 2018a
	Larus occidentalis	Collins et al. 2018a
	Larus spp. (large)	Collins et al. 2018a
	Limosa fedoa	Collins et al. 2018a
	Numenius phaeopus	Collins et al. 2018a
	Phalaropus fulicarius	Collins et al. 2018a
	Phalaropus lobatus	Collins et al. 2018a
	Phalaropus tricolor	Collins et al. 2018a
	Pluvialis squatarola	Collins et al. 2018a
	Ptychoramphus aleuticus	Collins et al. 2018a
	Rissa tridactyla	Collins et al. 2018a
	cf. *Sterna paradisaea*	Collins et al. 2018a
	Synthliboramphus antiquus	Collins et al. 2018a
	Synthliboramphus scrippsi	Collins et al. 2018a
	Tringa incana	Collins et al. 2018a
	Tringa semipalmatus	Collins et al. 2018a
	Uria aalge	Collins et al. 2018a
Aves: Gruiformes (crane-like birds)	cf. *Antigone canadensis*	Collins et al. 2018a
	Fulica americana	Collins et al. 2018a
Aves: Cathartiformes (New World vultures)	*Gymnogyps amplus*	Collins et al. 2018a
Aves: Accipitriformes (eagles, hawks, etc.)	*Buteo jamaicensis*	Collins et al. 2018a
	Buteo lagopus	Collins et al. 2018a
	Elanus leucurus	Collins et al. 2018a
	Haliaeetus leucocephalus	Collins et al. 2018a

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Aves: Falconiformes (falcons)	*Caracara cheriway*	Collins et al. 2018a
	Falco peregrinus	Collins et al. 2018a
	Falco sparverius	Collins et al. 2018a
Aves: Columbiformes (doves and pigeons)	*Patagioenas fasciata*	Collins et al. 2018a
	Zenaida macroura	Collins et al. 2018a
Aves: Strigiformes (owls)	*Asio flammeus*	Collins et al. 2018a
	Asio priscus	Collins et al. 2018a
	Athene cunicularia	Collins et al. 2018a
	Tyto alba	Collins et al. 2018a
Aves: Piciformes (woodpeckers, etc.)	*Colaptes auratus*	Collins et al. 2018a
	Melanerpes formicivorus	Collins et al. 2018a
	Sphyrapicus ruber	Collins et al. 2018a
Aves: Passeriformes (perching birds)	*Agelaius phoeniceus*	Collins et al. 2018a
	Agelaius tricolor	Collins et al. 2018a
	Aphelocoma insularis	Collins et al. 2018a
	cf. *Bombycilla cedrorum*	Collins et al. 2018a
	cf. *Calamospiza melanocorys*	Collins et al. 2018a
	Catharus guttatus	Collins et al. 2018a
	Catharus ustulatus	Collins et al. 2018a
	cf. *Chondestes grammacus*	Collins et al. 2018a
	cf. *Contopus sordidulus*	Collins et al. 2018a
	Corvus brachyrhynchos	Collins et al. 2018a
	Corvus corax	Collins et al. 2018a
	Eremophila alpestris	Collins et al. 2018a
	Euphagus cyanocephalus	Collins et al. 2018a
	cf. *Gymnorhinus cyanocephalus*	Collins et al. 2018a

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Aves: Passeriformes (perching birds) (continued)	*Haemorhous mexicanus*	Collins et al. 2018a
	cf. *Haemorhous purpureus*	Collins et al. 2018a
	cf. *Icterus bullockii*	Collins et al. 2018a
	Ixoreus naevius	Collins et al. 2018a
	Junco hyemalis	Collins et al. 2018a
	Lanius ludovicianus	Collins et al. 2018a
	Melospiza melodia	Collins et al. 2018a
	Mimus polyglottos	Collins et al. 2018a
	Molothrus ater	Collins et al. 2018a
	cf. *Oreoscoptes montanus*	Collins et al. 2018a
	Oreothlypis celata	Collins et al. 2018a
	Passerculus sandwichensis	Collins et al. 2018a
	Passerella iliaca	Collins et al. 2018a
	Pheucticus melanocephalus	Collins et al. 2018a
	Pipilo maculatus	Collins et al. 2018a
	cf. *Pipilo chlorurus*	Collins et al. 2018a
	Piranga ludoviciana	Collins et al. 2018a
	Salpinctes obsoletus	Collins et al. 2018a
	Sayornis saya	Collins et al. 2018a
	cf. *Sayornis nigricans*	Collins et al. 2018a
	Setophaga coronata	Collins et al. 2018a
	cf. *Sialia currucoides*	Collins et al. 2018a
	cf. *Sialia mexicana*	Collins et al. 2018a
	Spinus psaltria	Collins et al. 2018a
	Spinus tristis	Collins et al. 2018a
	Spizella passerina	Collins et al. 2018a

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Aves: Passeriformes (perching birds) (continued)	*Sturnella neglecta*	Collins et al. 2018a
	Thryomanes bewickii	Collins et al. 2018a
	cf. *Troglodytes aedon*	Collins et al. 2018a
	Turdus migratorius	Collins et al. 2018a
	cf. *Tyrannus vociferans*	Collins et al. 2018a
	Xanthocephalus xanthocephalus	Collins et al. 2018a
	Zonotrichia atricapilla	Collins et al. 2018a
	Zonotrichia leucophrys	Collins et al. 2018a
	Zonotrichia sp.	Collins et al. 2018a
Mammalia	Undetermined sea mammal	Ainis et al. 2011
Mammalia: Eulipotyphla ("insectivores")	*Sorex ornatus*	Walker 1980, Cushing et al. 1984, Guthrie 1993, 1998, 2005, Ainis et al. 2011
Mammalia: Rodentia	*Microtus miguelensis*	Guthrie 1993, 1998
	Peromyscus maniculatus	Walker 1980, Guthrie 1993, 1998, Ainis et al. 2011, Ainis and Vellanoweth 2012, Shirazi et al. 2018
	Peromyscus nesodytes	Walker 1980, Cushing et al. 1984, Guthrie 1993, 1998, Ainis et al. 2011, Ainis and Vellanoweth 2012, Shirazi et al. 2018
Mammalia: Chiroptera (bats)	*Desmodus stocki*	Guthrie 1993, 1998
Mammalia: Carnivora	*Canis familiaris*	Rick et al. 2008
	Spilogale gracilis	Walker 1980, Cushing et al. 1984
	Urocyon littoralis	Rick et al. 2009, Ainis et al. 2011
Mammalia: Carnivora: Pinnipedia	*Arctocephalus townsendi*	Walker and Craig 1979
	Callorhinus ursinus	Walker and Craig 1979
	Enhydra lutris	Walker and Craig 1979, Guthrie 1993
	Eumetopias jubatus	Walker and Craig 1979
	Mirounga angustirostris	Walker and Craig 1979
	Phoca vitulina	Walker and Craig 1979

Appendix Table A-1-c (continued). Fossil vertebrate taxa reported from San Miguel Island; all are of Quaternary age.

Group	Taxon	References
Mammalia: Carnivora: Pinnipedia (continued)	*Zalophus californianus*	Walker and Craig 1979
Mammalia: Proboscidea	*Mammuthus columbi*	Pigati et al. 2017
	Mammuthus exilis	Pigati et al. 2017
Mammalia: Artiodactyla	*Odocoileus* sp.	Vellanoweth et al. 2003 (early Holocene cultural context, thought to have been brought from mainland)
Mammalia: Cetacea	Cetacea undetermined	Bremner 1933, Johnson 1972, Erlandson et al. 1996

Appendix Table A-1-d. Ichnofossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Q	References
Invertebrate ichnofossils	*Diopatra*-like worm burrow	–	Y	–	–	Kies 1982
	General bioturbation	Y	Y	Y	–	Kies 1982, Bartling and Abbott 1983
Vertebrate ichnofossils	Alcid eggshells	–	–	–	Y	Guthrie 1993
	Bird eggshells	–	–	–	Y	Guthrie 1998
	Chendytes lawi eggshells	–	–	–	Y	Guthrie 2005
	Probable alcid nesting burrows	–	–	–	Y	Guthrie 1993, 1998, 2005

Appendix Table A-1-e. Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera	**Foraminifera overall**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
	Allomorphina cretacea	Y	–	–	–	–	–	–	Weaver 1969b
	Allomorphina macrostoma	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Allomorphina paleocenica	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Ammobaculites cubensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Ammobaculites* cf. *A. midwayana*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Ammobaculites sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Ammodiscus glabratus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Ammodiscus cf. *A. incertus*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Amphimorphina californica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Amphimorphina ignota	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Anomalina crassisepta	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Anomalina dorri aragonensis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Anomalina garzaensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Anomalina regina	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Anomalina salinasensis	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Anomalina cf. *A. dorri aragonensis*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Anomalina sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	"*Anomalina*" *rubiginosa*	Y	–	–	–	–	–	–	Weaver 1969b
	Anomalinoides henbesti	Y	–	–	–	–	–	–	Weaver 1969b
	Anomalinoides stephensoni	Y	–	–	–	–	–	–	Weaver 1969b
	Anomalinoides cf. *A. popenoei*	Y	–	–	–	–	–	–	Weaver 1969b
	Anomalinoides sp.?	Y	–	–	–	–	–	–	Weaver 1969b
	Astacolus tricarinella	Y	–	–	–	–	–	–	Weaver 1969b
	Astacolus sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Asterigerina crassaformis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Astrorhiza sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Baggatella sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Baggina californica	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Baggina robusta	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Bandyella greatvalleyensis	Y	–	–	–	–	–	–	Weaver 1969b

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Bathysiphon eocenica*	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Bathysiphon vitta	Y	–	–	–	–	–	–	Weaver 1969b
	Bifarina eleganta	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bifarina nuttalli	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Bigenerina sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Bolivina advena	–	–	–	Y	–	Y	–	Weaver and Doerner 1969b
	Bolivina aragonensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Bolivina californica	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Bolivina incrassata	Y	–	–	–	–	–	–	Weaver 1969b
	Bolivina marginata	–	–	–	Y	Y	Y	–	Weaver and Doerner 1969b
	Bolivina midwayensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bolivina pisciformis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina salinasensis	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Bolivina cf. *B. kleinpelli*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bolivina sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina arkadelphiana midwayensis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cacumenata	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina callahani	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina carlsoni	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina corrugata	–	–	Y	–	–	–	–	Kies 1982
	Bulimina curtissima	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina guayabalensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina jacksonensis welcomensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina macilenta	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina microcostata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina ovata	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Bulimina pupoides*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina sculptilis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina sculptilis brevis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. callahani*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. consanguinea*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. guayabalensis*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina aff. *B. inflata*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Bulimina cf. *B. kleinpelli*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. microcostata*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. pachecoensis*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. pupoides*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina aff. *B. pyrula*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina aff. *B. sculptilis*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Bulimina spp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Buliminella carseyi	Y	–	–	–	–	–	–	Weaver 1969b
	Buliminella curta	–	–	–	Y	Y	Y	–	Weaver and Doerner 1969b
	Buliminella elegantissima	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Buliminella grata	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Buliminella grata convoluta	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Buliminella subfusiformis	–	–	–	Y	–	Y	–	Weaver and Doerner 1969b
	Buliminella vitrea	Y	–	–	–	–	–	–	Weaver 1969b
	Buliminella sp.	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Cassidulina globosa	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cassidulina laevigata carinata	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Cassidulina cf. *C. pulchella*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Chiloguembelina parallela	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Chiloguembelina* sp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Chilostomella cylindroides	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Chilostomella hadleyi	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Chilostomella cf. *C. cylindroides*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Chilostomelloides eocenica	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Chilostomelloides oviformis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cibicides fortunatus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides grimsdalei	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cibicides laimingi	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cibicides pachyderma	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cibicides strophopunctatus	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Cibicides subspirata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cibicides cf. *C. relizensis*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Cibicides cf. *C. stephensoni*	Y	–	–	–	–	–	–	Weaver 1969b
	Cibicides sp.?	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	"*Cibicides* sp. B"	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicidoides validus	Y	–	–	–	–	–	–	Weaver 1969b
	Cibicidoides venezuelanus	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Clavigerinella jarvisi	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Clavihedbergella simplex	Y	–	–	–	–	–	–	Weaver 1969b
	Clavulinoides cf. *C. aspera*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Clavulinoides sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Cornuspira sp.?	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Cribrostomoides trinitatensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cyclammina cf. *C. incisa*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Cyclammina cf. *C. samanica*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Cyclammina* spp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina aculeata	Y	–	–	–	–	–	–	Weaver 1969b
	Dentalina approximata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina basiplanata	Y	–	–	–	–	–	–	Weaver 1969b
	Dentalina catenula	Y	–	–	–	–	–	–	Weaver 1969b
	Dentalina colei	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina communis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina confluens	Y	–	–	–	–	–	–	Weaver 1969b
	Dentalina consobrina	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina gracilis	Y	–	–	–	–	–	–	Weaver 1969b
	Dentalina inornata	Y	–	–	–	–	–	–	Weaver 1969b
	Dentalina jacksonensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina legumen	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina obliqua	–	–	–	–	–	–	–	Weaver and Doerner 1969b
	Dentalina spinosa	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina cf. *D. consobrina*	Y	–	Y	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	Dentalina cf. *D. delicatula*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina cf. *D. soluta*	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Dentalina sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Dentalina spp.	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Dorothia bulletta	Y	Y	Y	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	Dorothia oxycona	Y	–	–	–	–	–	–	Weaver 1969b
	Dorothia pupa	Y	–	–	–	–	–	–	Weaver 1969b
	Dorothia sp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Eggerella elongata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Eggerella subconica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Eggerella* sp.?	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Ellipsoglandulina subobesa	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Ellipsoglandulina sp.?	Y	–	–	–	–	–	–	Weaver 1969b
	Ellipsonodosaria jarvisi	Y	–	–	–	–	–	–	Weaver 1969b
	Ellipsonodosaria? *jarvisi*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Ellipsonodosaria plummerae	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Ellipsonodosaria cf. *E. jarvisi*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Ellipsonodosaria sp. A	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Ellipsonodosaria spp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	"*Ellipsopolymorphina*" *velascoensis*	Y	–	–	–	–	–	–	Weaver 1969b
	Elphidium californicum	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Entosolenia orbignyana	Y	–	Y	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	"Eoglobigerina" *minutissima*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Epistomina eocenica	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Epistomina sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Epistominoides midwayensis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Eponides bandyi	Y	–	–	–	–	–	–	Weaver 1969b
	Eponides dorfi	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Eponides umbonata	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Eponides cf. *E. multicameratus*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Eponides sp.	Y	Y	–	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	"*Eponides*" *greatvalleyensis*	Y	–	–	–	–	–	–	Weaver 1969b
	Frondicularia cf. *F. chapmani*	Y	–	–	–	–	–	–	Weaver 1969b
	Frondicularia sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Gaudryina laevigata	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Gaudryina triangularis	Y	–	–	–	–	–	–	Weaver 1969b

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Gaudryina* cf. *G. bentonensis*	Y	–	–	–	–	–	–	Weaver 1969b
	Gaudryina cf. *G. pyramidata*	Y	–	–	–	–	–	–	Weaver 1969b
	Gaudryina sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Gaudryina sp.?	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Gavelinella eriksdalensis	Y	–	–	–	–	–	–	Weaver 1969b
	Gavelinella rubiginosa	Y	–	–	–	–	–	–	Weaver 1969b
	Globigerapsis kugleri	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina angustiumbilicata	–	–	–	Y	–	Y	–	Weaver and Doerner 1969b
	Globigerina boweri	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina bulloides	–	–	–	Y	–	Y	–	Weaver and Doerner 1969b
	Globigerina coalingensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina concinna	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Globigerina decepta	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina dissimilis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina foliata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina gravelli	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina linaperta	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina nitida	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina officinalis	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Globigerina senni	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina soldadoensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina soldadoensis angulosa	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina triangularis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina turgida	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina velascoensis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina yeguaensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Globigerina* cf. *G. primitiva*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina cf. *G. venezuelana*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina cf. *G. yeguaensis*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerina sp.	–	–	Y	Y	Y	–	–	Weaver and Doerner 1969a, Weaver and Doerner 1969b
	Globigerinella micra	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globigerinelloides caseyi	Y	–	–	–	–	–	–	Weaver 1969b
	Globigerinelloides messinae	Y	–	–	–	–	–	–	Weaver 1969b
	Globigerinita glutinata	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	"Globigerinoides" *higginsi*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globobulimina pacifica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia aequa	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia aragonensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia aspensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia bolivariana	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia broedermanni	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia bullbrooki	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia formosa formosa	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia formosa gracilis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia marksi	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia nicoli	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia pseudotopilensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia rex	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia spinuloinflata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia cf. *G. broedermanni*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia cf. *G. bullbrooki*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Globorotalia* cf. *G. pseudotopilensis*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia cf. *G. velascoensis*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia cf. *G. whitei*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia spp.	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Globorotalites spineus	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana arca	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana coronata	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana marianosi	Y	–	–	–	–	–	–	Douglas 1969
	Globotruncana petaloidea	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana pseudolinneiana	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana sigali	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana stuartiformis	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana cf. *G. patelliformis*	Y	–	–	–	–	–	–	Weaver 1969b
	Globotruncana sp.	Y	–	–	–	–	–	–	Weaver 1969b
	"*Globotruncana* sp. C"	Y	–	–	–	–	–	–	Weaver 1969b
	Glomospira charoides	Y	–	–	–	–	–	–	Weaver 1969b
	Glomospira gordialis	Y	–	–	–	–	–	–	Weaver 1969b
	Goesella sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Goesella spp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Gublerina cuvillieri	Y	–	–	–	–	–	–	Weaver 1969b
	Guttulina irregularis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Guttulina trigonula	Y	–	–	–	–	–	–	Weaver 1969b
	Gyroidina condoni	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Gyroidina florealis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Gyroidina orbicularis planata	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	"Gyroidina" *florealis*	Y	–	–	–	–	–	–	Weaver 1969b

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	"Gyroidina" *globosa*	Y	–	–	–	–	–	–	Weaver 1969b
	"Gyroidina" *nitida*	Y	–	–	–	–	–	–	Weaver 1969b
	"Gyroidina" *quadrata*	Y	–	–	–	–	–	–	Weaver 1969b
	Haplophragmoides californicus	Y	–	–	–	–	–	–	Weaver 1969b
	Haplophragmoides coalingensis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides cretaceous	Y	–	–	–	–	–	–	Weaver 1969b
	Haplophragmoides deflata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides eggeri	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides glabra	Y	–	–	–	–	–	–	Weaver 1969b
	Haplophragmoides kirki	Y	–	–	–	–	–	–	Weaver 1969b
	Haplophragmoides obliquicameratus	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides cf. *H. fraseri*	Y	–	–	–	–	–	–	Weaver 1969b
	Haplophragmoides spp.	Y	Y	Y	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	Haplophragmoides sp.?	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
	Hastigerina sp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Hedbergella amabilis	Y	–	–	–	–	–	–	Weaver 1969b
	Hedbergella holmdelensis	Y	–	–	–	–	–	–	Weaver 1969b
	Hedbergella loetterlei	Y	–	–	–	–	–	–	Weaver 1969b
	Hedbergella planispira	Y	–	–	–	–	–	–	Weaver 1969b
	Hedbergella cf. *H. delrioensis*	Y	–	–	–	–	–	–	Weaver 1969b
	Heterohelix moremani	Y	–	–	–	–	–	–	Weaver 1969b
	Heterohelix pulchra	Y	–	–	–	–	–	–	Weaver 1969b
	Heterohelix reussi	Y	–	–	–	–	–	–	Weaver 1969b
	Heterohelix striata	Y	–	–	–	–	–	–	Weaver 1969b
	Hyperammina elongata	Y	–	Y	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	Karreriella chilostoma	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Karreriella mediaaguaensis*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Lagena proboscidialis	Y	–	–	–	–	–	–	Weaver 1969b
	Lagena spp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Lenticulina macrodisca	Y	–	–	–	–	–	–	Weaver 1969b
	Lenticulina muensteri	Y	–	–	–	–	–	–	Weaver 1969b
	Lenticulina navicular	Y	–	–	–	–	–	–	Weaver 1969b
	Lenticulina ovalis	Y	–	–	–	–	–	–	Weaver 1969b
	Lenticulina pseudosecans	Y	–	–	–	–	–	–	Weaver 1969b
	Lenticulina velascoensis	Y	–	–	–	–	–	–	Weaver 1969b
	Lenticulina warregonensis	Y	–	–	–	–	–	–	Weaver 1969b
	Lenticulina spp.	Y	–	–	–	–	–	–	Weaver 1969b
	"*Lenticulina* sp. B."	Y	–	–	–	–	–	–	Weaver 1969b
	Lingulina pygmaea	Y	–	–	–	–	–	–	Weaver 1969b
	Lituotuba sp.	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Loxostomum applinae	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Marginulina adunca	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Marginulina bullata	Y	–	–	–	–	–	–	Weaver 1969b
	Marginulina subbullata	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Marginulina troedssoni	Y	–	–	–	–	–	–	Weaver 1969b
	Marginulina cf. *M. regularis*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Marginulina spp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Marginulina? *glabra*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Marginulinopsis sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Martinottiella eocenica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Martinottiella cf. *M. petrosa*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina adolphina	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Nodogenerina lepidula*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodophthalmidium sp.?	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosarella advena	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosarella coalingensis	Y	–	–	–	–	–	–	Weaver 1969b
	Nodosarella winterei	Y	–	–	–	–	–	–	Weaver 1969b
	Nodosaria affinis	Y	–	–	–	–	–	–	Weaver 1969b
	Nodosaria arundinea	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria boffalorae	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria chirana	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria deliciae	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria ewaldi	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria holserica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria latejugata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria longiscata	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria pyrula	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria velascoensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria cf. *N. obscura*	Y	–	–	–	–	–	–	Weaver 1969b
	Nodosaria spp.	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Nonion costiferum	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Nonion incisum kernensis	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Nonion sp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Nonionella miocenica	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
	Osangularia cordieriana	Y	–	–	–	–	–	–	Weaver 1969b
	Osangularia texana	Y	–	–	–	–	–	–	Weaver 1969b
	Parrella cf. *P. culter midwayana*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Pelosina complanata*	Y	Y	Y	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	Planularia kochi	Y	–	–	–	–	–	–	Weaver 1969b
	Planularia truncana	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Planularia umbonata	Y	–	–	–	–	–	–	Weaver 1969b
	Planularia sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Planulina mascula	Y	–	–	–	–	–	–	Weaver 1969b
	Planulina cf. *P. venezuelana*	–	–	?	–	–	–	–	Weaver and Doerner 1969a
	Plectina garzaensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Plectofrondicularia kerni	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Plectofrondicularia miocenica	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
	Plectofrondicularia vaughani	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Pleurostomella acuta	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Pleurostomella alazanensis cubensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Pleurostomella nitida	Y	–	–	–	–	–	–	Weaver 1969b
	Pleurostomella subnodosa	Y	–	–	–	–	–	–	Weaver 1969b
	Pleurostomella torta	Y	–	–	–	–	–	–	Weaver 1969b
	Pleurostomella cf. *P. subnodosa*	Y	–	–	–	–	–	–	Weaver 1969b
	Pleurostomella sp. A	Y	–	–	–	–	–	–	Weaver 1969b
	Pleurostomella sp. B	Y	–	–	–	–	–	–	Weaver 1969b
	Praebulimina kickapooensis	Y	–	–	–	–	–	–	Weaver 1969b
	Praebulimina prolixa	Y	–	–	–	–	–	–	Weaver 1969b
	Praebulimina reussi	Y	–	–	–	–	–	–	Weaver 1969b
	Praebulimina spinata	Y	–	–	–	–	–	–	Weaver 1969b
	Praeglobotruncana gautierensis	Y	–	–	–	–	–	–	Weaver 1969b
	Praeglobotruncana helvetica	Y	–	–	–	–	–	–	Weaver 1969b, Douglas 1969
	Praeglobotruncana cf. *P. coarctata*	Y	–	–	–	–	–	–	Weaver 1969b

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Psammosphaera laevigata*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Pseudogaudryinella capitosa	Y	–	–	–	–	–	–	Weaver 1969b
	Pseudoglandulina conica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Pseudoglandulina ovata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Pseudoguembelina excolata	Y	–	–	–	–	–	–	Weaver 1969b
	Pseudohasterigerina micra	–	–	Y	–	–	–	–	Kies 1982
	Pseudotextularia cf. *P. deformis*	Y	–	–	–	–	–	–	Weaver 1969b
	Pullenia cretacea	Y	–	–	–	–	–	–	Weaver 1969b
	Pullenia eocenica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Pullenia quinqueloba	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Pullenia quinqueloba angusta	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Pullenia sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Racemiguembelina fructicosa	Y	–	–	–	–	–	–	Weaver 1969b
	Rectoglandulina spp.	Y	–	–	–	–	–	–	Weaver 1969b
	Reophax sp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Rhabdammina eocenica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Rhabdammina spp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Robertina sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus alatolimbatus	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus articulatus texanus	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus inornatus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus limbosus hockleyensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus mayi?	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus miocenicus	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Robulus propinquus cowlitzensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus pseudocultratus	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Robulus turbinatus*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus welchi	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus wilcoxensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. inornatus*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. kincaidi*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. mayi*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. smileyi*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Robulus spp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus? cf. *R. miocenicus*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Saccorhiza ramosa	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Saracenaria triangularis	Y	–	–	–	–	–	–	Weaver 1969b
	Saracenaria cf. *S. moresiana*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Schackoina multispinata	Y	–	–	–	–	–	–	Weaver 1969b
	Silicosigmoilina californica	Y	–	Y	–	–	–	–	Weaver 1969b, Weaver and Doerner 1969a
	Siphogenerina branneri	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Siphogenerina kleinpelli	–	–	–	?	–	Y	–	Weaver and Doerner 1969b
	Siphogenerina reedi	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Siphogenerina aff. *S. nuciformis*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Siphogenerina cf. *S. nuciformis*	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Spiroplectammina directa	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Spiroplectammina richardi	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Spiroplectammina semicomplanata	Y	–	–	–	–	–	–	Weaver 1969b
	Spiroplectammina tejonensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Tappanina sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Textularia midwayana	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Textularia ripleyensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Textularia* sp.	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Trifarina advena californica	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Tritaxia gaultinus	Y	–	–	–	–	–	–	Weaver 1969b
	Tritaxia jarvisi	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Tritaxilina colei	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Tritaxilina cubensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Trochammina texana	Y	–	–	–	–	–	–	Weaver 1969b
	Trochammina sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Trochammina spp.	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Trochamminoides sp.	Y	–	–	–	–	–	–	Weaver 1969b
	Turborotalia permicra	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Uvigerina churchi	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Uvigerina sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Uvigerinella californica	–	–	–	Y	Y	–	–	Weaver and Doerner 1969b
	Uvigerinella obesa	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
	Vaginulinopsis asperuliformis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Vaginulinopsis mexicana nudicostata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Valvulineria casitasensis	–	–	–	Y	–	–	–	Weaver and Doerner 1969b
	Valvulineria depressa	–	–	–	Y	–	Y	–	Weaver and Doerner 1969b
	Valvulineria infrequens	Y	–	–	–	–	–	–	Weaver 1969b
	Valvulineria jacksonensis welcomensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Valvulineria tumeyensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Valvulineria spp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Verneuilina triangulata	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Verneuilina cf. *V. triangulata*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Virgulina californiensis	–	–	–	Y	–	–	–	Weaver and Doerner 1969b

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Foraminifera (continued)	*Virgulina zetina*	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Virgulina zetina indirecta	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Virgulina sp.	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Virgulina sp.?	–	–	–	–	Y	–	–	Weaver and Doerner 1969b
	Foraminifera undetermined	Y	Y	Y	Y	–	Y	Y	Bremner 1933, Patet 1972, Kies 1982, Bartling and Abbott 1983
Coccolithophores	**Coccolithophores overall**	**Y**	**Y**	**Y**	**–**	**–**	**–**	**–**	**–**
	Arkhangelskiella cymbiformis	Y	–	–	–	–	–	–	Miller 1983
	Braarudosphaera bigelowii	Y	–	–	–	–	–	–	Miller 1983
	Broinsonia enormis	Y	–	–	–	–	–	–	Miller 1983
	Broinsonia parca	Y	–	–	–	–	–	–	Miller 1983
	Campylosphaera eodela	–	Y	–	–	–	–	–	Kies 1982
	Ceratolithoides aculeus	Y	–	–	–	–	–	–	Miller 1983
	Chiasmolithus gigas	–	–	Y	–	–	–	–	Kies 1982
	Chiastozygus plicatus	Y	–	–	–	–	–	–	Miller 1983
	Chiphragmalithus acanthodes	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Chiphragmalithus cristatus	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Chiphragmalithus dubius	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Coccolithites delus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Coccolithus crassus	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a, Kies 1982
	Coccolithus cribellum	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Coccolithus eminens	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Coccolithus formosus	–	–	Y	–	–	–	–	Kies 1982
	Coccolithus gigas	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Coccolithus grandis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Coccolithus staurion	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Coccolithophores (continued)	*Corollithion achylosum*	Y	–	–	–	–	–	–	Miller 1983
	Corollithion signum	Y	–	–	–	–	–	–	Miller 1983
	Cretarhabdus conicus	Y	–	–	–	–	–	–	Miller 1983
	Cretarhabdus crenulatus	Y	–	–	–	–	–	–	Miller 1983
	Cribrosphaera ehrenbergii	Y	–	–	–	–	–	–	Miller 1983
	Cyclococcolithus gammation	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Cylindralithus serratus	Y	–	–	–	–	–	–	Miller 1983
	Discoaster barbadiensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a, Kies 1982
	Discoaster diastypus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Discoaster distinctus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Discoaster falcatus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a, Kies 1982
	Discoaster kuepperi	–	Y	–	–	–	–	–	Weaver and Doerner 1969a, Kies 1982
	Discoaster lodoensis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a, Kies 1982
	Discoaster multiradiatus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a, Kies 1982
	Discoaster nonaradiatus	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Discoaster stradneri	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Discoaster sublodoensis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Discoaster tribrachiatus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Discolithus distinctus	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Discolithus ocellatus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Discolithus panarium	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Discolithus planus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Discolithus pulcher	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Eiffellithus eximius	Y	–	–	–	–	–	–	Miller 1983
	Eiffellithus trabeculatus	Y	–	–	–	–	–	–	Miller 1983
	Eiffellithus turriseiffeli	Y	–	–	–	–	–	–	Miller 1983

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Coccolithophores (continued)	*Ellipsolithus distichus*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Ellipsolithus macellus	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Fasciculithus involutus	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Gartnerago obliquum	Y	–	–	–	–	–	–	Miller 1983
	Helicosphaera seminulum lophota	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Helicosphaera seminulum seminulum	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Kamptnerius magnificus	Y	–	–	–	–	–	–	Miller 1983
	Lithastrinus floralis	Y	–	–	–	–	–	–	Miller 1983
	Lithastrinus grillii	Y	–	–	–	–	–	–	Miller 1983
	Lophodolithus mochlophorus	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Lophodolithus nascens	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Manivitella pemmatoidea	Y	–	–	–	–	–	–	Miller 1983
	Marthasterites furcatus	Y	–	–	–	–	–	–	Miller 1983
	Micrantholithus inaequalis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Micrantholithus vesper	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Microrhabdulus decoratus	Y	–	–	–	–	–	–	Miller 1983
	Micula staurophora	Y	–	–	–	–	–	–	Miller 1983
	Nannoconus sp.	Y	–	–	–	–	–	–	Miller 1983
	Parhabdolithus embergeri	Y	–	–	–	–	–	–	Miller 1983
	Parhabdolithus splendens	Y	–	–	–	–	–	–	Miller 1983
	Prediscosphaera cretacea	Y	–	–	–	–	–	–	Miller 1983
	Quadrum gartneri	Y	–	–	–	–	–	–	Miller 1983
	Quadrum nitidum	Y	–	–	–	–	–	–	Miller 1983
	Quadrum trifidum	Y	–	–	–	–	–	–	Miller 1983
	Rhabdosphaera crebra	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Rhabdosphaera inflata	–	–	Y	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-1-e (continued). Other fossil taxa reported from San Miguel Island in stratigraphic context.

Group	Taxon	Kj	Tpc	Tsp	Tr	Tsm	Tmsh	Q	References
Coccolithophores (continued)	*Rhabdosphaera morionum*	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Rhabdosphaera perlonga	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Rhabdosphaera rudis	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Rhabdosphaera semiformis	–	–	Y	–	–	–	–	Weaver and Doerner 1969a
	Rhabdosphaera tenuis	–	Y	Y	–	–	–	–	Weaver and Doerner 1969a
	Rhabdosphaera truncata	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Rhagodiscus angustus	Y	–	–	–	–	–	–	Miller 1983
	Scapholithus apertus	–	Y	–	–	–	–	–	Kies 1982
	Sphenolithus radians	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Vagalapilla imbricata	Y	–	–	–	–	–	–	Miller 1983
	Vagalapilla matalosa	Y	–	–	–	–	–	–	Miller 1983
	Vagalapilla octoradiata	Y	–	–	–	–	–	–	Miller 1983
	Watznaueria barnesae	Y	–	–	–	–	–	–	Miller 1983
	Zygodiscus bicrescenticus	Y	–	–	–	–	–	–	Miller 1983
	Zygodiscus diplogrammus	Y	–	–	–	–	–	–	Miller 1983
	Zygodiscus sp. aff. *Z. sigmoides*	Y	–	–	–	–	–	–	Miller 1983
	Zygrhablithus simplex	–	Y	–	–	–	–	–	Weaver and Doerner 1969a
	Zygrhablithus sp.	–	Y	–	–	–	–	–	Kies 1982
	Unidentified nannofossils	Y	Y	Y	–	–	–	–	Kies 1982, Kies and Abbott 1982, Bartling and Abbott 1983
Bacillariophyceae (diatoms)	Bacillariophyceae undetermined	–	–	–	–	–	Y	–	Weaver and Doerner 1969b
Rhodophyta (red algae)	*Melobesia mediocris*	–	–	–	–	–	–	Y	Ainis et al. 2011
	Corallinaceae undetermined	–	–	–	–	–	–	Y	Ainis et al. 2011
Other fossils	Fungal sclerotia	–	–	–	–	–	–	Y	Scott et al. 2010
	Unidentifiable macrofossils (Sespe equivalent?)	–	–	–	Y	–	–	–	Weaver and Doerner 1969a

Santa Rosa Island Records

The Santa Rosa Island records have been divided into five tables: Appendix Table A-2-a for fossil plants, Appendix Table A-2-b for fossil invertebrates, Appendix Table A-2-c for fossil vertebrates, Appendix Table A-2-d for ichnofossils, and Appendix Table A-2-e for other fossils.

As with the San Miguel Island tables, only those formations with records are included. Because the only record of fossil plants outside of Quaternary deposits is a mention of "carbonaceous fragments" in Avila and Weaver (1969), Appendix Table A-2-a presents only Quaternary fossils. All units have yielded invertebrate fossils, so no columns are omitted in Appendix Table A-2-b. Vertebrates are only present in Tsp (South Point Formation), Tr (Rincon Shale), Q (Quaternary), and possibly Tv (Vaqueros Formation) (Appendix Table A-2-c). Ichnofossils are only present in Tv (Vaqueros Formation), Tmbt (Beechers Bay Formation), Q (Quaternary), and possibly Ts (Sespe Formation) (Appendix Table A-2-d). Finally, other fossils are present in all units except Ts (Sespe Formation) (Appendix Table A-2-e). The unfossiliferous San Onofre Breccia has been excluded altogether.

The diatom taxa from Anderson et al. (2010) are all Holocene in age.

There are some contradictions between the text and tables in Avila and Weaver (1969), concerning which unit was the source for which fossils (Vaqueros and Rincon).

The list of bird taxa included in Orr (1968) is omitted because these specimens were re-evaluated in Collins et al. (2018a). Additionally, almost all of the other fossil taxa mentioned in Orr (1968) were previously mentioned in Orr (1960). Therefore, it was decided to omit the redundant later citation unless it provided additional details of note. Citations of "Orr 1960" can be understood as also valid for Orr (1968).

Isolated examples of petrified wood were observed at two locations on the island in June 2019; without any obvious way of determining the source(s) (although they are most likely from terrestrial Quaternary deposits), they were not included in the table.

Abbreviations for Santa Rosa Island stratigraphic units, used throughout Appendix A-2 tables:
Q = Quaternary deposits
Tmsh = Monterey Formation, shale member
Tmbt = Beechers Bay Formation
Tsm = "San Miguel Island" (=Santa Rosa Island) Volcanics
Tr = Rincon Formation
Tv = Vaqueros Formation
Ts = Sespe Formation
Tcd = Cozy Dell Shale
Tsp = South Point Formation

Appendix Table A-2-a. Fossil plant taxa reported from Santa Rosa Island; all are of Quaternary age.

Group	Taxon	References
Bryophyta (mosses)	Moss spores	Cole and Liu 1994
Lycopodiophyta (clubmosses, quillworts, spikemosses)	*Selaginella* cf. *S. bigelovii* spores	Anderson et al. 2010
	Spikemoss spores	Cole and Liu 1994
Polypodiopsida (ferns)	*Botrychium* spores	Anderson et al. unpublished data
	cf. *Botrychium* spores	Anderson et al. 2010
	cf. *Pellaea* spores	Anderson et al. 2010
	Polypodium californicum spores	Anderson et al. 2010
	Pteridium spores	Anderson et al. 2010
	Monolete psilate spores	Anderson et al. unpublished data
	Trilete psilate spores	Anderson et al. unpublished data
	Fern spores	Anderson et al. 2010
Pinophyta (conifers)	*Abies* sp. charcoal	Rick et al. 2012a
	Cupressus goveniana	Johnson 1977
	Cupressus pollen	Anderson et al. unpublished data
	cf. *Cupressus* sp.	Scott et al. 2017
	Picea pollen	Anderson et al. unpublished data
	Pinus muricata pollen	Cole and Liu 1994
	Pinus torreyana pollen	Cole and Liu 1994
	Pinus sp.	Scott et al. 2017, Anderson (pers. comm., April 2020)
	Pinus pollen	Anderson et al. 2010, Muhs et al. 2015, Anderson et al. unpublished data
	Pseudotsuga pollen	Anderson et al. unpublished data
	Cupressaceae charcoal	Rick et al. 2012a
	Cupressaceae pollen	Anderson et al. 2010
	Conifer wood	Scott et al. 2017
Magnoliophyta (flowering plants)	*Achillea*-type pollen	Anderson et al. 2010
	Alnus pollen	Anderson et al. 2010

Appendix Table A-2-a (continued). Fossil plant taxa reported from Santa Rosa Island; all are of Quaternary age.

Group	Taxon	References
Magnoliophyta (flowering plants) (continued)	*Ambrosia* pollen	Cole and Liu 1994, Anderson et al. 2010, Anderson et al. unpublished data
	Artemisia pollen	Cole and Liu 1994, Anderson et al. 2010, Anderson et al. unpublished data
	Baccharis pollen	Anderson et al. 2010, Anderson et al. unpublished data
	Baccharis-type pollen	Anderson et al. 2010
	Ceanothus cf. *C. arboreus* charcoal	Rick et al. 2012a
	Ceanothus sp. charcoal	Erlandson et al. 2011
	Chaenactis-type pollen	Anderson et al. 2010
	Cirsium pollen	Anderson et al. 2010
	Eriogonum pollen	Anderson et al. 2010, Anderson et al. unpublished data
	Eriogonum-type pollen	Cole and Liu 1994
	Erodium pollen	Anderson et al. 2010
	Helianthus pollen	Anderson et al. 2010
	Helianthus-type pollen	Anderson et al. 2010
	Ipomopsis/*Gilia* pollen	Anderson et al. 2010
	Plantago pollen	Anderson et al. 2010
	Polemonium pollen	Anderson et al. unpublished data
	Populus pollen	Anderson et al. unpublished data
	Prunus wood	Anderson (pers. comm., April 2020)
	Quercus pollen	Anderson et al. 2010, Muhs et al. 2015, Anderson et al. unpublished data
	Solidago pollen	Anderson et al. 2010
	Solidago-type pollen	Anderson et al. 2010
	Typha pollen	Anderson et al. unpublished data
	Amaranthaceae pollen	Anderson et al. unpublished data
	Apiaceae pollen	Anderson et al. 2010
	Asteraceae pollen	Cole and Liu 1994, Anderson et al. 2010, Muhs et al. 2015, Anderson et al. unpublished data

Appendix Table A-2-a (continued). Fossil plant taxa reported from Santa Rosa Island; all are of Quaternary age.

Group	Taxon	References
Magnoliophyta (flowering plants) (continued)	Bladderpod pollen	Cole and Liu 1994
	Brassicaceae pollen	Anderson et al. unpublished data
	Caryophyllaceae pollen	Anderson et al. 2010
	Cheno-am pollen	Anderson et al. 2010
	Chenopodiodeae pollen	Cole and Liu 1994
	Cyperaceae pollen	Cole and Liu 1994, Anderson et al. 2010, Anderson et al. unpublished data
	Fabaceae pollen	Anderson et al. 2010, Anderson et al. unpublished data
	Fagaceae pollen	Cole and Liu 1994
	Lactuceae pollen	Anderson et al. 2010
	Lamiaceae pollen	Cole and Liu 1994, Anderson et al. unpublished data
	Poaceae pollen	Cole and Liu 1994, Anderson et al. 2010, Anderson et al. unpublished data
	Polemoniaceae pollen	Anderson et al. 2010
	Rosaceae pollen	Anderson et al. 2010, Anderson et al. unpublished data
	Rose/sumac/buckthorn pollen	Cole and Liu 1994
	Typhaceae pollen	Cole and Liu 1994
	Angiosperm wood	Scott et al. 2017
Other plants	Charcoal	Broecker and Culp 1957, Orr 1960, Fergusson and Libby 1963, Cole and Liu 1994, Guthrie 1998, Erlandson et al. 1999, Anderson et al. 2010, Pinter et al. 2011, Muhs et al. 2015, Anderson et al. unpublished data
	Phytoliths	Anderson et al. 2010
	Rhizoconcretions	Dibblee and Ehrenspeck 1998
	Root and tree casts	Orr 1960
	“Spore #6”	Anderson et al. 2010
	Wood	Orr 1968

Appendix Table A-2-b. Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Porifera (sponges)	Sponge spicules	–	–	–	–	–	–	–	–	Y	Anderson et al. 2010
Cnidaria: Anthozoa: Scleractinia (stony corals)	*Astrangia* sp.	–	–	–	Y	–	–	–	–	–	Avila and Weaver 1969
	Balanophyllia elegans	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014, 2015
	Oculina panzana	–	–	–	?	–	–	–	–	–	Loel and Corey 1932
	Scleractinia undetermined	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
Mollusca	**Mollusca overall**	**–**	**Y**	**?**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
	Molluscan "reefs"	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Mollusca undetermined	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014, 2015
Mollusca: Polyplacophora (chitons)	*Cryptochiton stelleri*	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014
	Cyanoplax hartwegii	–	–	–	–	–	–	–	–	Y	Orr 1960
	Ischnochiton sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Katharina tunicata	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999
	Mopalia ciliata	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999
	Mopalia muscosa	–	–	–	–	–	–	–	–	Y	Orr 1960
	Stenoplax conspicua	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014
	Polyplacophora undetermined	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999
Mollusca: Bivalvia (clams, oysters, etc.)	**Bivalvia overall**	**–**	**Y**	**?**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
	Anomia vaquerosensis	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Antigona vaquerosensis	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Arca strongi	–	–	–	?	–	–	–	–	–	Loel and Corey 1932
	Cardita subquadrata	–	–	–	–	–	–	–	–	Y	Orr 1960
	Chione aff. *C. richthofeni*	–	–	–	Y	Y	–	–	–	–	Avila and Weaver 1969
	Chione temblorensis	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Chione temblorensis subtemblorensis	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Chione sp.?	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Clementia pertenuis conradiana*	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Corbula luteola	–	–	–	–	–	–	–	–	Y	Orr 1960
	Crassatellites granti	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Crassostrea? englekyi	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Loel and Corey 1932, Moore 1987
	Crassostrea titan subtitan	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Cumingia californica	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014, 2015
	Cytherea (*Cytherea*) sp.	–	–	–	–	Y	–	–	–	–	Hertlein 1928
	Cytherea (=*Antigona*?) sp.	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Diplodonta harfordi	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Diplodonta cf. *D. buwaldana*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Diplodonta cf. *D. orbella*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Dosinia cf. *D. merriami*	–	–	–	–	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Dosinia sp.	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Epilucina californica	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014, 2015
	Glans carpenteri	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014, 2015
	Glans sp.	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014, 2015
	Glycymeris subobsoleta	–	–	–	–	–	–	–	–	Y	Orr 1960
	Irus lamellifer	–	–	–	–	–	–	–	–	Y	Orr 1960
	Lyropecten miguelensis	–	–	–	Y	Y	–	–	–	–	Arnold 1906, Hertlein 1928, Loel and Corey 1932, Avila and Weaver 1969, Smith 1991, Dibblee and Ehrenspeck 1998

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Lyropecten pretiosus*	–	–	–	Y	–	–	–	Y	–	Loel and Corey 1932, Avila and Weaver 1969, Smith 1991
	Macoma arctata	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Macoma nasuta	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Macoma sespeensis	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Modiolus ynezianus	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Modiolus ynezianus lagunanus	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Mytilus californianus	–	–	–	–	–	–	–	–	Y	Orr 1960, Fergusson and Libby 1963, Erlandson et al. 1999, Muhs et al. 2014, 2015
	Mytilus expansus	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Mytilus sp.	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014
	Nutricola tantilla	–	–	–	–	–	–	–	–	Y	Orr 1960
	Ostrea eldridgei	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Ostrea vespertina	–	–	–	Y	Y	–	–	–	–	Dibblee and Ehrenspeck 1998
	<u>*Ostrea vespertina loeli*</u>	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Loel and Corey 1932, Avila and Weaver 1969, Smith 1991
	Ostrea cf. *O. hermanni*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Ostrea sp.	–	–	–	Y	Y	–	–	Y	–	Avila and Weaver 1969
	Ostrea sp. reworked from Miocene	–	–	–	–	–	–	–	–	RI	Orr 1960
	Panope cf. *P. generosa*	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Pecten hertleini	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Pecten magnolia	–	–	–	Y	Y	–	–	Y	–	Bremner 1932, Avila and Weaver 1969

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Pecten perrini*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Pecten sespeensis	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Pecten cf. *P. crassicardo*	–	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Petricola sp.	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Pholadidea penita	–	–	–	–	–	–	–	–	Y	Orr 1960
	Pholadidea sp.	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Pinna stocktoni	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Placunanomia granti	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Loel and Corey 1932, Moore 1987
	Psamosolen gabbiana	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Pteria hertleini	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Pteria rositae	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Loel and Corey 1932
	Pycnodonte? (*Pycnodonte*?) *wiedeyi*	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Moore 1987
	Saxicava pholadis	–	–	–	–	–	–	–	–	Y	Orr 1960
	Saxidomus vaquerosensis	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Saxidomus sp.	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014
	Septifer bifurcatus	–	–	–	–	–	–	–	–	Y	Orr 1960, Erlandson et al. 1999
	Solen gravidus baileyi	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Solen sp.	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Spisula cf. *S. catilliformis*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Spondylus perrini	–	–	–	Y	Y	Y	Y	–	–	Loel and Corey 1932, Avila and Weaver 1969, Smith 1991
	Spondylus sp.	–	–	–	Y	–	–	–	–	–	Avila and Weaver 1969

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Tagelus clarki*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Tagelus clarki?	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Tivela inezana	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Tivela stultorum	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999
	Venus virginiana	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Zirfaea sp.	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Undetermined oyster	–	–	–	–	Y	–	–	–	–	Moore 1987
	Undetermined pecten	–	–	?	–	–	–	–	–	–	J. Hoffman (pers. obs., 2019)
	Bivalvia undetermined	–	Y	–	–	–	Y	–	–	–	Weaver and Doerner 1969a, Dibblee and Ehrenspeck 1998
Mollusca: Gastropoda (snails)	**Gastropoda overall**	**–**	**–**	**–**	**Y**	**Y**	**–**	**–**	**–**	**Y**	**–**
	Acanthinucella punctulata	–	–	–	–	–	–	–	–	Y	Orr 1960
	Acmaea asmi	–	–	–	–	–	–	–	–	Y	Orr 1960
	Acmaea digitalis	–	–	–	–	–	–	–	–	Y	Orr 1960
	Acmaea mitra	–	–	–	–	–	–	–	–	Y	Orr 1960
	Acmaea patina	–	–	–	–	–	–	–	–	Y	Orr 1960
	Acmaea persona	–	–	–	–	–	–	–	–	Y	Orr 1960
	Acmaea sp.	–	–	–	–	Y	–	–	–	Y	Avila and Weaver 1969, Erlandson et al. 1999, Muhs et al. 2014
	Acmaea spp.	–	–	–	–	–	–	–	–	Y	Muhs et al. 2015
	Aletes sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Amphissa columbiana	–	–	–	–	–	–	–	–	Y	Orr 1960
	Amphissa versicolor	–	–	–	–	–	–	–	–	Y	Orr 1960
	Aptyxis luteopicta	–	–	–	–	–	–	–	–	Y	Orr 1960
	Astraea sp.?	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Bittium purpureum	–	–	–	–	–	–	–	–	Y	Orr 1960

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Bittium* sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Bruclarkia sp.	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Calicantharus fortis	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014
	Californiconus californicus	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014, 2015
	Callianax biplicata	–	–	–	–	–	–	–	–	Y	Orr 1960, Erlandson et al. 1999, Muhs et al. 2014, 2015
	Calliostoma augustinensis	–	–	–	Y	–	–	–	–	–	Hertlein 1928, Loel and Corey 1932
	Calliostoma sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Calyptraea costellata	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Calyptraea filosa	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Cancellaria sp.	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Chlorostoma brunnea	–	–	–	–	–	–	–	–	Y	Orr 1960
	Chlorostoma funebralis	–	–	–	–	–	–	–	–	Y	Orr 1960, Erlandson et al. 1999, Muhs et al. 2015
	Chlorostoma sp.	–	–	–	–	–	–	–	–	Y	Muhs et al. 2014, 2015
	Conus sp.	–	–	–	–	Y	–	–	–	Y	Avila and Weaver 1969, Muhs et al. 2014
	Crepidula aculeata	–	–	–	–	–	–	–	–	Y	Orr 1960
	Crepidula adunca	–	–	–	–	–	–	–	–	Y	Orr 1960
	Crepidula diminutiva	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Crepidula norrisiarum	–	–	–	–	–	–	–	–	Y	Orr 1960
	Crepidula perforans	–	–	–	–	–	–	–	–	Y	Orr 1960
	Crepidula cf. *C. praerupta*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Cypraea n. sp. “A”	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Discurra insessa	–	–	–	–	–	–	–	–	Y	Orr 1960

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Fissurella volcano*	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014, 2015
	Haliotis cracherodii	–	–	–	–	–	–	–	–	Y	Orr 1960, Erlandson et al. 1999
	Haliotis rufescens	–	–	–	–	–	–	–	–	Y	Orr 1960, Fergusson and Libby 1963, Muhs et al. 2014, 2015
	Haliotis sp.	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999, Muhs et al. 2014, 2015
	Haliotis spp.	–	–	–	–	–	–	–	–	Y	Muhs et al. 2015
	Helminthoglypta ayresiana	–	–	–	–	–	–	–	–	Y	Cockerell 1938c, Orr 1960, Erlandson et al. 1999, Muhs et al. 2015, Schumann et al. 2016
	Hipponix antiquatus	–	–	–	–	–	–	–	–	Y	Orr 1960
	Hipponix cranioides	–	–	–	–	–	–	–	–	Y	Orr 1960
	Hipponix tumens	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014, 2015
	Homalopoma luridum	–	–	–	–	–	–	–	–	Y	Orr 1960
	Lacuna sp.	–	–	–	–	–	–	–	–	Y	Orr 1960, Erlandson et al. 1999
	Littorina planaxis	–	–	–	–	–	–	–	–	Y	Orr 1960
	Littorina scutulata	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2015
	Lottia conus	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014
	Lottia limatula	–	–	–	–	–	–	–	–	Y	Orr 1960
	Lottia pelta	–	–	–	–	–	–	–	–	Y	Orr 1960
	Lottia scabra	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014, 2015
	Megastraea undosa	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Mitra idae*	–	–	–	–	–	–	–	–	Y	Orr 1960
	Mitra sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Mitrella gausapata	–	–	–	–	–	–	–	–	Y	Orr 1960
	Nassarius (Catilon) churchi	–	–	–	Y	–	–	–	–	–	Hertlein 1928, Loel and Corey 1932, Addicott 1965
	Nerita beali?	–	–	–	Y	Y	–	–	–	–	Avila and Weaver 1969
	Neostylidium eschrichtii	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014
	Ocenebra circumtexta	–	–	–	–	–	–	–	–	Y	Orr 1960
	Ocenebra foveolata	–	–	–	–	–	–	–	–	Y	Orr 1960
	Ocenebra sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Ocinebrina lurida	–	–	–	–	–	–	–	–	Y	Orr 1960
	Petaloconchus sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Physa sp.	–	–	–	–	–	–	–	–	Y	Schumann et al. 2016
	Polinices recluzianus andersoni	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969
	Pseudomelatoma torosa	–	–	–	–	–	–	–	–	Y	Orr 1960
	Pseudomelatoma sp.	–	–	–	–	–	–	–	–	Y	Orr 1960
	Purpura milicentana	–	–	–	Y	–	–	–	–	–	Avila and Weaver 1969
	Purpura topangensis	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Rapana imperialis	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Loel and Corey 1932, Avila and Weaver 1969
	Rapana vaquerosensis	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969, Smith 1991, Dibblee and Ehrenspeck 1998
	Siphonaria brannani	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014
	Tegula pulligo	–	–	–	–	–	–	–	–	Y	Orr 1960
	Thais emarginata	–	–	–	–	–	–	–	–	Y	Orr 1960

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Mollusca: Gastropoda (snails) (continued)	*Thylacodes squamigerus*	–	–	–	–	–	–	–	–	Y	Orr 1960, Erlandson et al. 1999, Muhs et al. 2014, 2015
	Trimusculus reticulatus	–	–	–	–	–	–	–	–	Y	Orr 1960
	Trophosycon ocoyana	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Turritella bicarina n. subsp.	–	–	–	?	–	–	–	–	–	Loel and Corey 1932
	Turritella inezana	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Avila and Weaver 1969, Smith 1991, Dibblee and Ehrenspeck 1998
	Turritella inezana santana	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Turritella inezana supervariant	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Turritella ocoyana	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969, Dibblee and Ehrenspeck 1998
	Turritella ocoyana bosei	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Turritella temblorensis	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Avila and Weaver 1969, Dibblee and Ehrenspeck 1998
	Turritella temblorensis reworked from Rincon Formation	–	–	–	–	RO	–	–	–	RI	Muhs et al. 2015
	<u>*Turritella temblorensis tritschi*</u>	–	–	–	Y	Y	–	–	–	–	Hertlein 1928, Loel and Corey 1932, Avila and Weaver 1969
	Turritella cf. *T. ocoyana topangaensis*	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Turritella sp.	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Turritella sp. reworked from Miocene	–	–	–	–	–	–	–	–	RI	Orr 1960
	Gastropoda undetermined	–	–	–	–	–	–	–	–	Y	Orr 1960
Annelida (segmented worms)	*Serpula* cf. *S. coreyi*	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Arthropoda	**Arthropoda overall**	**Y**	**–**	**–**	**Y**	**U**	**–**	**–**	**–**	**Y**	**–**
Arthropoda: Crustacea: Cirripedia (barnacles)	*Balanus tintinnabulum*	–	–	–	–	–	–	–	–	Y	Orr 1960
	Balanus sp.	–	–	–	Y	–	–	–	–	Y	Loel and Corey 1932, Erlandson et al. 1999
	Pollicipes polymerus	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999
	Tetraclita rubescens	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999
	Cirripedia undetermined	–	–	–	U	U	–	–	–	–	J. Tweet (pers. obs., 2019)
Arthropoda: Crustacea: Decapoda: Brachyura (crabs)	Brachyura undetermined	–	–	–	U	U	–	–	–	–	J. Tweet (pers. obs., 2019)
Arthropoda: Crustacea: Ostracoda (seed shrimp)	*Candona* sp.	–	–	–	–	–	–	–	–	Y	Schumann et al. 2016
	Cypridopsis sp.	–	–	–	–	–	–	–	–	Y	Schumann et al. 2016
	Ilyocypris sp.	–	–	–	–	–	–	–	–	Y	Schumann et al. 2016
	Ostracoda undetermined	Y	–	–	–	–	–	–	–	–	Weaver and Doerner 1969a
Echinodermata: Echinoidea (sea urchins)	**Echinoidea overall**	**–**	**–**	**–**	**Y**	**Y**	**–**	**–**	**–**	**Y**	**–**
	Brissus kewi	–	–	–	Y	–	–	–	–	–	Grant and Hertlein 1938
	Brissus latecarinatus?	–	–	–	Y	–	–	–	–	–	Grant and Hertlein 1938
	Cassidulus mexicanus	–	–	–	Y	?	–	–	–	–	Grant and Hertlein 1938
	Echinarachnius norrisi	–	–	–	Y	Y	–	–	–	–	Loel and Corey 1932, Grant and Hertlein 1938
	Echinarachnius vaquerosensis	–	–	–	Y	–	–	–	–	–	Grant and Hertlein 1938
	Kewia fairbanksi	–	–	–	Y	–	–	–	–	–	Bremner 1932
	Kewia fairbanksi n. var.?	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932
	Linthia sp.	–	–	–	Y	–	–	–	–	–	Loel and Corey 1932, Grant and Hertlein 1938
	Lytechinus coreyi	–	–	–	Y	–	–	–	–	–	Grant and Hertlein 1938
	Lytechinus pictus?	–	–	–	Y	–	–	–	–	–	Grant and Hertlein 1938

Appendix Table A-2-b (continued). Fossil invertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Ts	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Echinodermata: Echinoidea (sea urchins)	*Scutella vaquerosensis*	–	–	–	Y	–	–	–	–	–	Bremner 1932, Loel and Corey 1932
	Strongylocentrotus droebachiensis	–	–	–	–	–	–	–	–	Y	Orr 1960, Muhs et al. 2014
	Strongylocentrotus franciscanus	–	–	–	–	–	–	–	–	Y	Orr 1960
	Strongylocentrotus sp.	–	–	–	–	–	–	–	–	Y	Erlandson et al. 1999
Other invertebrates	"Vaqueros megafossils"	–	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Reworked Rincon Formation fossils	–	–	–	–	RO	–	–	–	RI	Orr 1968, Muhs et al. 2015
	Shell debris	–	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Unidentifiable shell material in dunes	–	–	–	–	–	–	–	–	Y	Dibblee and Ehrenspeck 1998

Appendix Table A-2-c. Fossil vertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tv	Tr	Q	References
Chondrichthyes (shark and rays)	Ray teeth	–	U	U	–	Hoffman 2017
	Shark teeth	–	U	U	–	Hoffman 2017
Actinopterygii (ray-finned fish)	*Hexagrammos* sp.	–	–	–	Y	Erlandson et al. 2011
	Sebastes sp.	–	–	–	Y	Erlandson et al. 1999
	Sebastes spp.	–	–	–	Y	Erlandson et al. 2011
	Semicossyphus pulcher	–	–	–	Y	Erlandson et al. 1999
	Clupeidae undetermined	–	–	–	Y	Erlandson et al. 2011
	Clupeiformes undetermined	–	–	–	Y	Erlandson et al. 1999
	Cottidae undetermined	–	–	–	Y	Erlandson et al. 2011
	Embiotocidae undetermined	–	–	–	Y	Erlandson et al. 2011
	Pleuronectidae undetermined	–	–	–	Y	Erlandson et al. 2011
	Actinopterygii undetermined	–	–	–	Y	Erlandson et al. 2011

Appendix Table A-2-c (continued). Fossil vertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tv	Tr	Q	References
Amphibia	Amphibia undetermined	–	–	–	Y	Mead et al. 2018
Amphibia: Anura (frogs)	*Pseudacris* sp. near *P. regilla*	–	–	–	Y	Mead et al. 2018
	Anura undetermined	–	–	–	Y	Mead et al. 2018
Amphibia: Caudata (salamanders)	*Batrachoseps* sp.	–	–	–	Y	Mead et al. 2004
Reptilia	Reptilia undetermined	–	–	–	Y	Erlandson et al. 1999
Reptilia: Lacertilia	*Elgaria multicarinata*	–	–	–	Y	Erlandson et al. 1999
Reptilia: Serpentes	*Crotalus viridis*	–	–	–	Y	Guthrie 1998
Aves	**Aves overall**	**–**	**–**	**–**	**Y**	**–**
	"Shore birds"	–	–	–	Y	Orr 1960
	Aves undetermined	–	–	–	Y	Erlandson et al. 1999, 2011, Mead et al. 2004, Collins et al. 2018a
Aves: Anseriformes (ducks and geese)	**Anseriformes overall**	**–**	**–**	**–**	**Y**	**–**
	Anas carolinensis	–	–	–	Y	Howard 1944
	Anas crecca	–	–	–	Y	Collins et al. 2018a
	Anas platyrhynchos	–	–	–	Y	Collins et al. 2018a
	Anas sp.	–	–	–	Y	Howard 1944, Collins et al. 2018a
	Anser albifrons	–	–	–	Y	Collins et al. 2018a
	Anser caerulescens	–	–	–	Y	Erlandson et al. 2011, Collins et al. 2018a, Anderson et al. unpublished data
	Anser rossi	–	–	–	Y	Collins et al. 2018a
	Branta bernicla	–	–	–	Y	Collins et al. 2018a
	Branta canadensis	–	–	–	Y	Collins et al. 2018a
	Branta canadensis ?*canadensis*	–	–	–	Y	Howard 1944
	Branta canadensis ?*leucopareia*	–	–	–	Y	Howard 1944
	Branta canadensis ?*minima*	–	–	–	Y	Howard 1944
	Branta hutchinsii	–	–	–	Y	Collins et al. 2018a
	cf. *Branta canadensis*	–	–	–	Y	Erlandson et al. 2011

Appendix Table A-2-c (continued). Fossil vertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tv	Tr	Q	References
Aves: Anseriformes (ducks and geese) (continued)	*Chendytes lawi*	–	–	–	Y	Guthrie 1998, Jones et al. 2008, Erlandson et al. 2011, Collins et al. 2018a
	Mareca americana	–	–	–	Y	Collins et al. 2018a
	Mareca strepera	–	–	–	Y	Collins et al. 2018a
	Mergus serrator	–	–	–	Y	Collins et al. 2018a
	Spatula clypeata	–	–	–	Y	Collins et al. 2018a
	Anatidae undetermined	–	–	–	Y	Erlandson et al. 2011
	Anserini undetermined	–	–	–	Y	Erlandson et al. 2011, Collins et al. 2018a
Aves: Podicipediformes (grebes)	*Podiceps nigricollis*	–	–	–	Y	Collins et al. 2018a
Aves: Procellariiformes (petrels)	*Ardenna grisea*	–	–	–	Y	Collins et al. 2018a
	Ardenna sp.	–	–	–	Y	Collins et al. 2018a
	Phoebastria albatrus	–	–	–	Y	Collins et al. 2018a
	cf. *Phoebastria nigripes*	–	–	–	Y	Collins et al. 2018a
	Puffinus opisthomelas	–	–	–	Y	Collins et al. 2018a
Aves: Suliformes (gannets and cormorants)	*Morus reyanus*	–	–	–	Y	Guthrie 1998, Collins et al. 2018a
	Phalacrocorax penicillatus	–	–	–	Y	Collins et al. 2018a
	Phalacrocorax spp.	–	–	–	Y	Erlandson et al. 2011, Collins et al. 2018a
Aves: Charadriiformes (gulls, waders, etc.)	*Cerorhinca monocerata*	–	–	–	Y	Collins et al. 2018a
	Fratercula dowi	–	–	–	Y	Guthrie et al. 1999
	Haematopus bachmani	–	–	–	Y	Erlandson et al. 2011
	Larus sp. (large)	–	–	–	Y	Collins et al. 2018a
	Phalaropus fulicarius	–	–	–	Y	Collins et al. 2018a
	Ptychoramphus aleuticus	–	–	–	Y	Collins et al. 2018a
	Rissa tridactyla	–	–	–	Y	Collins et al. 2018a
	Synthliboramphus antiquus	–	–	–	Y	Collins et al. 2018a
	Uria aalge	–	–	–	Y	Collins et al. 2018a

Appendix Table A-2-c (continued). Fossil vertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tv	Tr	Q	References
Aves: Cathartiformes (New World vultures)	*Gymnogyps amplus*	–	–	–	Y	Collins et al. 2018a
Aves: Accipitriformes (eagles, hawks, etc.)	*Buteo jamaicensis*	–	–	–	Y	Collins et al. 2018a
	Haliaeetus leucocephalus	–	–	–	Y	Collins et al. 2018a
Aves: Falconiformes (falcons)	*Caracara cheriway*	–	–	–	Y	Howard 1962, Guthrie 1998, Collins et al. 2018a
Aves: Columbiformes (doves and pigeons)	*Patagioenas fasciata*	–	–	–	Y	Collins et al. 2018a
Aves: Strigiformes (owls)	<u>*Asio priscus*</u>	–	–	–	Y	Howard 1964b, Guthrie 1998, Collins et al. 2018a
	cf. *Asio flammeus*	–	–	–	Y	Erlandson et al. 2011
	Athene cunicularia	–	–	–	Y	Collins et al. 2018a
	Tyto alba	–	–	–	Y	Erlandson et al. 2011, Collins et al. 2018a
Aves: Piciformes (woodpeckers, etc.)	*Colaptes auratus*	–	–	–	Y	Collins et al. 2018a
Aves: Passeriformes (perching birds)	*Aphelocoma insularis*	–	–	–	Y	Collins et al. 2018a
	Corvus brachyrhynchos	–	–	–	Y	Collins et al. 2018a
	Corvus corax	–	–	–	Y	Collins et al. 2018a
	Lanius ludovicianus	–	–	–	Y	Collins et al. 2018a
	Melospiza melodia	–	–	–	Y	Collins et al. 2018a
	Passerella iliaca	–	–	–	Y	Collins et al. 2018a
	Passeriformes undetermined	–	–	–	Y	Erlandson et al. 2011
	Pheucticus melanocephalus	–	–	–	Y	Collins et al. 2018a
	Pipilo maculatus	–	–	–	Y	Collins et al. 2018a
	Turdus migratorius	–	–	–	Y	Collins et al. 2018a
	Xanthocephalus xanthocephalus	–	–	–	Y	Collins et al. 2018a
	Zonotrichia atricapilla	–	–	–	Y	Collins et al. 2018a
	Zonotrichia leucophrys	–	–	–	Y	Collins et al. 2018a
Mammalia	**Mammalia overall**	**–**	**U**	**U**	**Y**	**–**

Appendix Table A-2-c (continued). Fossil vertebrate taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tv	Tr	Q	References
Mammalia (continued)	Mouse and/or shrew bones	–	–	–	Y	Erlandson et al. 1999
	Possible sea mammal	–	–	–	Y	Erlandson et al. 1999
	Mammalia undetermined	–	–	–	Y	Erlandson et al. 2011, Mead et al. 2018
Mammalia: Eulipotyphla ("insectivores")	*Sorex ornatus*	–	–	–	Y	Guthrie 1998
Mammalia: Rodentia	*Microtus* sp.	–	–	–	Y	Mead et al. 2004
	<u>*Peromyscus nesodytes*</u>	–	–	–	Y	Wilson 1936, Orr 1968, Guthrie 1998, Agenbroad et al. 2005
	Rodentia undetermined	–	–	–	Y	Erlandson et al. 2011
Mammalia: Carnivora	*Canis familiaris*	–	–	–	Y	Rick et al. 2008
	Enhydra lutris	–	–	–	Y	Orr 1960, Mitchell 1966, Muhs et al. 2015
	Phoca vitulina cf.	–	–	–	Y	Erlandson et al. 2011
	Urocyon littoralis	–	–	–	Y	Orr 1968, Rick et al. 2009
	Otariinae undetermined	–	–	–	Y	Orr 1960
	Pinnipedia undetermined	–	–	–	Y	Orr 1968, Erlandson et al. 2011
Mammalia: Proboscidea	*Mammuthus columbi*	–	–	–	Y	Agenbroad 2012, Pigati et al. 2017
	<u>*Mammuthus exilis*</u>	–	–	–	Y	Stearns 1873, Stock and Furlong 1928, Stock 1935, Agenbroad 2012, Pigati et al. 2017
	Mammuthus sp.	–	–	–	Y	Pigati et al. 2017
Mammalia: Sirenia	Sirenia undetermined	–	U	U	–	J. Hoffman (pers. obs., 2019)
Mammalia: Cetacea	Cetacea undetermined	–	U?	U?	Y	Stock and Furlong 1928; Orr 1960, 1968, Hoffman 2017
Other vertebrates	Fish debris (bones, scales, teeth, etc.)	Y	–	Y	Y	Avila and Weaver 1969, Weaver and Doerner 1969a, Erlandson et al. 1999, Mead et al. 2004
	Vertebrata undetermined	–	–	Y	Y	Avila and Weaver 1969, Erlandson et al. 1999, 2011

Appendix Table A-2-d. Ichnofossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Ts	Tv	Tr	Tmbt	Q	References
Invertebrate ichnofossils	Arthropod coprolites	–	–	–	–	Y	Scott et al. 2017
	General bioturbation	–	Y	–	–	–	Dibblee and Ehrenspeck 1998
	Invertebrate burrows	?	U	U	Y	–	Nuccio 1977, Nuccio and Woolley 1998, Hoffman 2017, J. Hoffman (pers. obs., 2019)
	Ophiomorpha-like burrows	–	Y	–	Y	–	Howell and McLean 1976, Dibblee and Ehrenspeck 1998
	Clasts bored by pholadid bivalves	–	–	–	–	Y	Muhs et al. 2015
	Termite frass	–	–	–	–	Y	Scott et al. 2017
Vertebrate ichnofossils	Barn owl pellets	–	–	–	–	Y	Guthrie 1998

Appendix Table A-2-e. Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera	**Foraminifera overall**	**Y**	**Y**	**–**	**Y**	**Y**	**Y**	**Y**	**–**	**–**
	Alabamina wilcoxensis californica	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Allomorphina spp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Ammobaculites spp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Anomalina regina minor	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Anomalina cf. *A. patella*	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Anomalina sp.	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Astigerina crassaformis umbilicatula	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Baggina cancriformis	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Baggina robusta	–	–	–	Y	–	Y	Y	–	Avila and Weaver 1969
	Baggina aff. *B. cancriformis*	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Baggina cf. *B. robusta*	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Bathysiphon eocenica	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bathysiphon aff. *B. brosgei*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Bathysiphon* sp.	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Bathysiphon spp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bifarina eleganta	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina advena	–	–	–	Y	–	Y	Y	–	Avila and Weaver 1969
	Bolivina advena striatella	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bolivina advena?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bolivina brevior	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bolivina californica	–	–	–	Y	Y	Y	Y	–	Avila and Weaver 1969
	Bolivina conica	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Bolivina crenulata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina cuneiformis	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Bolivina gardnerae	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina gracilis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina imbricata	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bolivina jacksonensis tumeyensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina kleinpelli	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina marginata	–	–	–	Y	Y	Y	Y	–	Avila and Weaver 1969
	Bolivina salinasensis	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bolivina scabrata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina spiralis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina cf. *B. bramletti*	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Bolivina cf. *B. salinasensis*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bolivina sp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bolivina spp.	–	–	–	–	–	Y	–	–	Avila and Weaver 1969
	Bulimina adamsi	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina corrugata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Bulimina curtissima*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina elongata	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina guayabalensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina inflata	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969
	Bulimina inflata alligata	–	–	–	Y	Y	–	–	–	Avila and Weaver 1969
	Bulimina inflata alligata?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bulimina instabilis	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina kugleri	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina macilenta	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina microcostata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina ovata	?	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina pseudotorta	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969, Nuccio 1977, Nuccio and Woolley 1998
	Bulimina pupoides	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina sculptilis brevis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina stalacta	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina versa	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina aff. *B. inflata alligata*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Bulimina cf. *B. instabilis*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. intermedia*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Bulimina cf. *B. montereyana*	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Bulimina spp.	?	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Buliminella curta	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Buliminella curta?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Buliminella subfusiformis	–	–	–	–	Y	–	Y	–	Avila and Weaver 1969
	Buliminella aff. *B. intorta*	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Buliminella* cf. *B. subfusiformis*	–	–	–	–	Y	–	Y	–	Avila and Weaver 1969
	Cancris cf. *C. brongniartii*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cassidulina globosa	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cassidulina sp.	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Cassidulina spp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Chilostomella cylindroides	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Chilostomella hadleyi	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides americanus	–	–	–	Y	Y	–	Y	–	Avila and Weaver 1969
	Cibicides cushmani	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides felix	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides floridanus	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Cibicides hodgei	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides laimingi	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides ouachitaensis alhambrensis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides relizensis	–	–	–	Y	–	Y	–	–	Avila and Weaver 1969
	Cibicides sassei	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides spiropunctatus	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides cf. *C. laurisae*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicides sp.	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Cibicidoides venezuelanus	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cibicidoides cf. *C. coalingensis*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Clavulina aff. *C. subrotunda*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cyclammina incisa	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cyclammina pacifica	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cyclammina samanica	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Cyclammina sp.	–	–	–	Y	Y	–	–	–	Avila and Weaver 1969

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Cyclammina* spp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina colei	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina communis	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina consobrina	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Dentalina eocenica	?	?	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina jacksonensis	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina mucronata	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina pauperata	–	Y	–	Y	–	Y	Y	–	Avila and Weaver 1969, Weaver and Doerner 1969a
	Dentalina quadrulata	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Dentalina soluta	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina aff. *D. barnesi*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Dentalina cf. *D. quadrulata*	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Dentalina cf. *D. sherborni*	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina aff. *D. wilcoxensis*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dentalina sp.	–	–	–	Y	Y	–	–	–	Avila and Weaver 1969
	Dentalina spp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Discammina eocenica	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Discorbis sp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Dorothia principiensis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Eggerella elongata	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Eggerella subconica	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Eggerella spp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Ellipsonodosaria paleocenica	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Ellipsonodosaria sp. A.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	"Eoglobigerina" *minutissima*	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Epistominella* sp.?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Eponides nanus	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Eponides umbonata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Frondicularia foliacea	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969, Nuccio 1977, Nuccio and Woolley 1998
	Gaudryina aff. *G. rudita*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Gaudryina sp.	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Gaudryina spp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina angustiumbilicata	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Globigerina bulloides	Y	–	–	Y	–	–	Y	–	Avila and Weaver 1969, Weaver and Doerner 1969a
	Globigerina coalingensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina concinna	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Globigerina decepta	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina nitida	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina pseudobulloides	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina triloculinoides	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina aff. *G. boweri*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerina spp.	Y	–	–	Y	Y	–	Y	–	Avila and Weaver 1969, Weaver and Doerner 1969a
	Globigerinella micra	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globigerinita glutinata	–	–	–	Y	–	–	?	–	Avila and Weaver 1969
	Globigerinoides aff. *G. obliqua*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globobulimina pacifica	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia cocoaensis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia crassa aequa	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Globorotalia multiloculata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Globorotalia nicoli*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Gyroidina orbicularis obliquata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Gyroidina orbicularis planata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Gyroidina soldanii	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Gyroidina soldanii octocamerata	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Gyroidina sp.	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Hantkenina dumblei	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides deflata	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides emaciatum	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides kirki	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides obliquicameratus	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides aff. *H. excavata*	?	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides cf. *H. mauricensis*	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Haplophragmoides sp.	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Haplophragmoides spp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Hastigerinella eocanica	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Hemicristellaria beali	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969
	Hormosina sp.?	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Lagena acuticostata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Lagena costata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Lagena vulgaris	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Lenticulina theta	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Lenticulina cf. *L. convergens*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Loxostomum applinae	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Marginulina laevisulca	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Marginulina subbullata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Marginulina* aff. *M. karreriana*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Marginulina spp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Marginulina sp.?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Marginulinopsis wilcoxensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Marginulinopsis sp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Martinottiella eocenica	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina adolphina	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina advena	–	–	–	Y	Y	Y	Y	–	Avila and Weaver 1969
	Nodogenerina cooperensis	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina kressenbergensis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina lepidula	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina sanctaecrucis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodogenerina cf. *N. advena hughesi*	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Nodogenerina sp.	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Nodosaria arundinea	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria chirana	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria deliciae	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria ewaldi	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria longiscata	Y	Y	–	–	Y	–	Y	–	Avila and Weaver 1969, Weaver and Doerner 1969a
	Nodosaria parexilis	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Nodosaria pyrula	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria velascoensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nodosaria sp.	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Nodosaria spp.	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nonion costiferum	–	–	–	Y	–	Y	Y	–	Avila and Weaver 1969

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Nonion durhami*	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Nonion mediocostatum	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Nonion cf. *N. communis*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Nonion cf. *N. incisum*	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Nonion sp.	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Orbulina universa	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Planulina baggi	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Plectofrondicularia concepcionensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Plectofrondicularia miocenica	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Plectofrondicularia miocenica directa	–	–	–	–	Y	–	Y	–	Avila and Weaver 1969
	Plectofrondicularia searsi	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Plectofrondicularia trinitatensis	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Plectofrondicularia vokesi	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Plectofrondicularia aff. *P. miocenica*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Plectofrondicularia cf. *P. miocenica directa*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Plectofrondicularia sp.	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Pseudoglandulina conica	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Pullenia quinqueloba angusta	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Pulvinulinella relizensis	–	–	–	–	Y	–	–	–	Avila and Weaver 1969
	Quadrimorphina sp.?	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Reophax sp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Rhabdammina eocenica	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Rhabdammina aff. *R. abyssorum*	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Rhabdammina spp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus alatolimbatus	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Robulus arcuatostriatus carolinianus*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus kreyenhagenensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus limbosus hockleyensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus miocenicus	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Robulus pseudovortex	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus simplex	–	–	–	Y	Y	–	–	–	Avila and Weaver 1969
	Robulus smileyi	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Robulus welchi	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. deformis*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. euglypheus*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. gerlandi*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Robulus cf. *R. gyroscalprus*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus aff. *R. mayi*	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Robulus cf. R. *mayi*	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Robulus cf. *R. midwayensis*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus cf. *R. reedi*	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Robulus cf. *R. terryi*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Robulus sp.	–	–	–	Y	Y	–	Y	–	Avila and Weaver 1969
	Robulus spp.	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Silicosigmoilina californica	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Siphogenerina branneri	–	–	–	Y	–	Y	Y	–	Avila and Weaver 1969, Nuccio 1977, Nuccio and Woolley 1998
	Siphogenerina collomi	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969
	Siphogenerina hughesi	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Siphogenerina kleinpelli	–	–	–	Y	–	Y	Y	–	Avila and Weaver 1969
	Siphogenerina nuciformis	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Siphogenerina reedi*	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969, Nuccio 1977, Nuccio and Woolley 1998
	Siphogenerina reedi?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Siphogenerina transversa	–	–	–	Y	Y	–	–	–	Avila and Weaver 1969
	Siphogenerina sp.	–	–	–	Y	Y	–	Y	–	Avila and Weaver 1969
	"Sphaeroidina gredalensis"	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Spirobolivina sp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Spiroplectammina tejonensis	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Spiroplectammina trinitatensis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Spiroplectammina sp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Spiroplectoides curta	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Textularia eocaena	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Textularia sp.	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Textulariella barretti	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Textulariella spp.	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Tritaxilina colei	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Trochammina clairbornensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Trochammina deformis	–	?	–	–	–	–	–	–	Weaver and Doerner 1969a
	Trochammina cf. *T. globigeriniformis*	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Trochammina sp.	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Trochamminoides contortus	–	?	–	–	–	–	–	–	Weaver and Doerner 1969a
	Trochamminoides sp.?	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Truncatulina sp.?	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Turborotalia peripheroronda	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Turborotalia praescitula	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Uvigerina churchi	?	?	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Uvigerina churchi demicostata*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Uvigerina elongata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Uvigerina garzaensis	–	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Uvigerina garzaensis nudorobusta	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Uvigerinella californica	–	–	–	Y	Y	Y	Y	–	Avila and Weaver 1969
	Uvigerinella californica ornata	–	?	–	–	–	–	Y	–	Avila and Weaver 1969, Weaver and Doerner 1969a
	Uvigerinella californica parva	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Uvigerinella obesa	–	–	–	Y	–	–	Y	–	Avila and Weaver 1969
	Uvigerinella obesa impolita	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Uvigerinella sp.	–	–	–	Y	Y	–	–	–	Avila and Weaver 1969
	"*Uvigerinella* aff. *U. obesa*"	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Valvulineria casitasensis	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Valvulineria chirana	Y	Y	–	–	–	–	–	–	Weaver and Doerner 1969a
	Valvulineria depressa	–	–	–	Y	–	Y	Y	–	Avila and Weaver 1969, Nuccio 1977, Nuccio and Woolley 1998
	Valvulineria indiscriminata	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Valvulineria jacksonensis welcomensis	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Valvulineria miocenica	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969
	Valvulineria miocenica?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Valvulineria ornata	–	–	–	–	–	Y	Y	–	Avila and Weaver 1969
	Valvulineria ornata?	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Valvulineria williami	–	–	–	Y	–	–	–	–	Avila and Weaver 1969
	Valvulineria aff. *V. chirana*	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a
	Valvulineria sp.	Y	–	–	–	Y	–	–	–	Avila and Weaver 1969, Weaver and Doerner 1969a
	Verneuilina scabra?	Y	–	–	–	–	–	–	–	Weaver and Doerner 1969a

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Foraminifera (continued)	*Virginulina californiensis*	–	–	–	–	Y	–	Y	–	Avila and Weaver 1969
	Virginulina dibollensis	–	?	–	–	–	–	–	–	Weaver and Doerner 1969a
	Virginulina sp.	–	–	–	–	–	–	Y	–	Avila and Weaver 1969
	Foraminifera undetermined	–	–	Y	Y	–	Y	–	–	Avila and Weaver 1969, Patet 1972, McLean et al. 1976b, Nuccio 1977, Nuccio and Woolley 1998
Radiolaria	Radiolaria undetermined	–	–	–	–	–	–	–	Y	Anderson et al. 2010
Coccolithophores	Reworked Eocene-age nannofossils	–	–	RI	RI	–	–	–	–	McLean et al. 1976a
Bacillariophyceae (diatoms)	**Diatoms overall**	**Y**	**Y**	**–**	**Y**	**–**	**–**	**Y**	**Y**	**–**
	Achnanthes brevipes	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Achnanthes brevipes var. *intermedia*	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Amphora granulata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Aulacoseira granulata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Coscinodiscus marginatus	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Cosmioneis pusilla	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Cymbella sp.	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Epithemia adnata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Eunotia arcus	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Eunotia monodon	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Eunotia muscicola var. *tridentula*	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Eunotia pectinalis var. *undulata*	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Eunotia triodon	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Gyrosigma acuminatum	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Hantzschia amphioxys	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Luticola mutica	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Lyrella lyroides	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Meridion circulare var. *constrictum*	–	–	–	–	–	–	–	Y	Anderson et al. 2010

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Bacillariophyceae (diatoms) (continued)	*Navicula cincta*	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Navicula jaagi	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Navicula tripunctata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia bryophila	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia communis	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia commutata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia filiformis	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia granulata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia palea	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia scalpelliformis	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Nitzschia sociabilis	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Opephora schwartzii	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Paralia sulcata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Pinnularia appendiculata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Pinnularia borealis	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Rhaphoneis surirella	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Rhopalodia gibba	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Rhopalodia gibberula	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Rhopalodia musculus	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Sellaphora bacillum	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Sellaphora laevissima	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Sellaphora pupula	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Stauroneis undulata	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Surirella striatula	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Synedra acus	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Synedra gaillonii	–	–	–	–	–	–	–	Y	Anderson et al. 2010

Appendix Table A-2-e (continued). Other fossil taxa reported from Santa Rosa Island in stratigraphic context.

Group	Taxon	Tsp	Tcd	Tv	Tr	Tsm	Tmbt	Tmsh	Q	References
Bacillariophyceae (diatoms) (continued)	*Tabularia tabulata*	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Thalassiosira eccentrica	–	–	–	–	–	–	–	Y	Anderson et al. 2010
	Bacillariophyceae undetermined	Y	Y	–	Y	–	–	Y	–	Weaver and Doerner 1969a, Howell and McLean 1976
Chrysophyceae (golden algae)	Chrysophyte somatocysts	–	–	–	–	–	–	–	Y	Anderson et al. 2010
Other fossils	Fungal mycorrhizae, vesicular-arbuscular	–	–	–	–	–	–	–	Y	Anderson et al. unpublished data
	Fungal sclerotia	–	–	–	–	–	–	–	Y	Scott et al. 2010, 2017

Santa Cruz Island Records

As with San Miguel Island and Santa Rosa Island, the records for Santa Cruz Island are divided between fossil plants (Appendix Table A-3-a), fossil invertebrates (Appendix Tables A-3-b and A-3-c), fossil vertebrates (Appendix Table A-3-d), ichnofossils (Appendix Table A-3-e), and other fossils (Appendix Tables A-3-f and A-3-g). The large number of fossiliferous formations necessitated dividing the records of fossil invertebrates and other fossils into two tables; the division between pre- and post-Miocene volcanic units was chosen.

Records noted nowhere else but in the collections of the San Diego Natural History Museum have "SDNHM" in "References".

Rand (1931) reported several fossil taxa from "throughout" the "Domengine Formation", which is now divided into the Cañada Formation, Jolla Vieja Formation, and Cozy Dell Shale. Although only the Cañada Formation is noted for producing significant amounts of macrofossils, because Rand specifically wrote "throughout" rather than specify some part of the "Domengine Formation", these taxa are placed in all three formations with the records noted as "U" rather than "Y".

Kies (1982) reported numerous coccolith taxa, the great majority of which are listed as [X.] [species]. In addition, there are a number of typographic errors in the species names. Reconstructing the binomials is not feasible at this time. Typos follow corrected names if known.

Records in Snyder (2000) are of early to middle Holocene age.

Abbreviations for Santa Cruz Island stratigraphic units, used throughout Appendix A-3 tables:
Q = post-Middle Anchorage Alluvium Quaternary
Qma = Middle Anchorage Alluvium
Qph = Potato Harbor Formation
Tb = Blanca Formation
Tmsh = Monterey Formation, shale member
Tmbt = Beechers Bay Formation
Tsc = Santa Cruz Island Volcanics
Tso = San Onofre Breccia
Tr = Rincon Formation
Tv = Vaqueros Formation
Tcd = Cozy Dell Shale
Tjv = Jolla Vieja Formation
Tc = Cañada Formation
Tp = Pozo Formation
K = subsurface Cretaceous rocks

Unfossiliferous units are excluded (Mesozoic igneous and metamorphic rocks).

Appendix Table A-3-a. Fossil plant taxa reported from Santa Cruz Island in stratigraphic context.

Group	Taxon	Tc	Tcd	Qph	Q	References
Bryophytes (mosses)	*Brachytheciastrum velutinum*	–	–	–	Y	Grant 2016
	?*Eurhynchiastrum pulchellum*	–	–	–	Y	Grant 2016
	cf. *Sciurohypnum oedipodium*	–	–	–	Y	Grant 2016
Polypodiopsida (ferns)	*Botrychium* spores	–	–	–	Y	Anderson et al. unpublished data
	Polypodium spores	–	–	–	Y	Anderson et al. unpublished data
	Monolete psilate spores	–	–	–	Y	Anderson et al. unpublished data
	Monolete sculptured spores	–	–	–	Y	Anderson et al. unpublished data
	Monolete spores with perine (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Trilete spores (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Trilete psilate spores	–	–	–	Y	Anderson et al. unpublished data
	Trilete sculptured spores	–	–	–	Y	Anderson et al. unpublished data
Pinophyta (conifers)	*Cupressus goveniana*	–	–	–	Y	Chaney and Mason 1930
	Cupressus pollen	–	–	–	Y	Anderson et al. unpublished data
	Picea pollen	–	–	–	Y	Grant 2016, Anderson et al. unpublished data
	Pinus radiata	–	–	–	Y	Grant 2016
	Pinus remorata	–	–	–	Y	Chaney and Mason 1930, Axelrod 1983, 1986, Grant 2016
	Pinus pollen	–	–	–	Y	Grant 2016, Anderson et al. unpublished data
	Pseudotsuga menziesii	–	–	–	Y	Chaney and Mason 1930, Bremner 1932, Pinter et al. 1998, Anderson et al. 2008, Grant 2016
	Pseudotsuga pollen	–	–	–	Y	Grant 2016, Anderson et al. unpublished data
	Cupressaceae pollen	–	–	–	Y	Grant 2016
Magnoliophyta (flowering plants)	*Alnus* pollen	–	–	–	Y	Anderson et al. unpublished data
	Ambrosia pollen	–	–	–	Y	Anderson et al. unpublished data
	Arceuthobium campylopodum	–	–	–	Y	Chaney and Mason 1930
	Arceuthobium pollen	–	–	–	Y	Anderson et al. unpublished data
	Arctostaphylos sp.	–	–	–	Y	Chaney and Mason 1930

Appendix Table A-3-a (continued). Fossil plant taxa reported from Santa Cruz Island in stratigraphic context.

Group	Taxon	Tc	Tcd	Qph	Q	References
Magnoliophyta (flowering plants) (continued)	*Arctostaphylos* pollen	–	–	–	Y	Anderson et al. unpublished data
	Artemisia pollen	–	–	–	Y	Anderson et al. unpublished data
	Ceanothus thyrsiflorus	–	–	–	Y	Chaney and Mason 1930
	Ceanothus sp.	–	–	–	Y	Anderson et al. unpublished data
	Cercidiphyllum sp.?	–	Y	–	–	Shapiro 1998
	Cercocarpus sp.	–	–	–	Y	Anderson et al. unpublished data
	Cholla pollen (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Cornus pubescens (list) or *californica* (text)	–	–	–	Y	Chaney and Mason 1930
	Corylus sp.	–	–	–	Y	Anderson et al. unpublished data
	Erodium pollen (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Eriogonum pollen	–	–	–	Y	Anderson et al. unpublished data
	Galium pollen	–	–	–	Y	Anderson et al. unpublished data
	Garrya elliptica	–	–	–	Y	Chaney and Mason 1930
	Geranium pollen	–	–	–	Y	Anderson et al. unpublished data
	Myrica californica	–	–	–	Y	Chaney and Mason 1930
	Populus pollen	–	–	–	Y	Anderson et al. unpublished data
	Quercus pollen	–	–	–	Y	Anderson et al. unpublished data
	Ribes pollen (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Salix pollen	–	–	–	Y	Anderson et al. unpublished data
	Amaranthaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Apiaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Asteraceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Asteraceae pollen (Liguliflorae) (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Brassicaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Caryophyllaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Cyperaceae pollen	–	–	–	Y	Anderson et al. unpublished data

Appendix Table A-3-a (continued). Fossil plant taxa reported from Santa Cruz Island in stratigraphic context.

Group	Taxon	Tc	Tcd	Qph	Q	References
Magnoliophyta (flowering plants) (continued)	cf. Ericaceae leaf	–	–	–	Y	Grant 2016
	Euphorbiaceae pollen (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Fabaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Liliaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Onagraceae pollen (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Poaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Poaceae pollen (Cerealia) (late Holocene)	–	–	–	Y	Anderson et al. unpublished data
	Rhamnaceae pollen	–	–	–	Y	Anderson et al. unpublished data
	Rosaceae pollen	–	–	–	Y	Anderson et al. unpublished data
Other plants	Charcoal	–	–	–	Y	Anderson 1998, Pinter et al. 1998, 2011, Snyder 2000, Grant 2016, Anderson et al. unpublished data
	Fossilized wood casts	Y	–	–	–	Shapiro 1998
	Opalized stem and trunk casts	–	–	–	Y	Johnson 1967
	Root casts	–	–	Y	Y	Weaver and Meyer 1969, Snyder 2000
	Seeds of uncertain affinities (four morphotypes)	–	–	–	Y	Chaney and Mason 1930
	Wood and leaves of undetermined affinities	–	–	–	Y	Grant 2016

Appendix Table A-3-b. Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Cnidaria: Anthozoa: Scleractinia (stony corals)	*Balanophyllia* cf. *B. variabilis*	–	Y	–	–	–	–	–	Shapiro 1998
Bryozoa (moss animals)	Bryozoa undetermined	–	–	–	–	Y	–	–	Bereskin and Edwards 1969
Brachiopoda (lamp shells)	*Discinisca* sp.	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
Mollusca	**Mollusca overall**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
	Mollusca undetermined	Y	Y	?	–	–	–	–	Rand 1933, Doerner 1969, Kies 1982

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Mollusca: Bivalvia (clams, oysters, etc.)	**Bivalvia overall**	**Y**	**Y**	**U**	**Y**	**Y**	**Y**	**Y**	**–**
	Acila sp. reworked from Cretaceous or Paleocene	–	–	–	–	–	–	RI	Stuart 1976
	Acutostrea? *miguelensis*	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Amusium cf. *A. lompocensis*	–	–	–	–	–	–	Y	Bereskin and Edwards 1969, Shapiro 1998
	Amussiopecten vanvlecki	–	–	–	–	Y	Y	–	Rand 1931, Bremner 1932, Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998
	Anadara sp.	–	Y	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Antigona vaquerosensis	–	–	–	–	Y	–	–	Loel and Corey 1932
	Callocardia simiensis	Y	–	–	–	–	–	–	Rand 1931, 1933, Shapiro 1998
	Cardium vaquerosensis	–	–	–	–	Y	–	–	Loel and Corey 1932
	Cardium cf. *C. cooperi*	–	Y	–	–	–	–	–	Bremner 1932
	Cardium cf. *C. linteum*	Y	–	–	–	–	–	–	Shapiro 1998
	Cardium sp.	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Cardium sp.?	Y	Y	–	–	–	–	–	Shapiro 1998
	Chione schencki?	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Chione temblorensis	Y	–	–	–	Y	–	–	Shapiro 1998
	Chione sp.	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Chlamys sespensis	–	–	–	–	Y	–	–	Shapiro 1998
	Clementia pertenuis	–	–	–	–	Y	–	–	Shapiro 1998
	Clementia pertenuis conradiana	–	–	–	–	Y	–	–	Loel and Corey 1932, Shapiro 1998
	Clementia sp.	–	–	–	–	Y	Y	–	Bremner 1932, Shapiro 1998
	Corbula cf. *C. parilis*	–	U	U	U	–	–	–	Rand 1931
	Crassatella collina	Y	–	–	–	–	–	–	Shapiro 1998
	Crassatella sp.	Y	–	–	–	–	–	–	Squires 2018
	Crassatellites cf. *C. semidentata*	–	Y	–	–	–	–	–	Bremner 1932

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Crassatellites* sp.	–	Y	–	–	–	–	–	Bremner 1932
	Crassostrea? englekyi	–	–	–	–	Y	Y	–	Bremner 1932, Loel and Corey 1932
	Crassostrea? *englekyi*?	–	–	–	–	–	–	Y	Bereskin and Edwards 1969, Shapiro 1998
	Cucullaea (*Cyphoxis*) *mathewsoni*	Y	–	–	–	–	–	–	Rand 1931
	Cucullaea sp.	Y	–	–	–	–	–	–	Doerner 1969, Shapiro 1998, Squires 2018
	Cytherea (=*Antigona*?) sp.	–	–	–	–	Y	–	–	Loel and Corey 1932
	Diplodonta parilis	–	–	–	–	–	Y	–	Bremner 1932
	Diplodonta cf. *D. orbella*	–	–	–	–	Y	Y	–	Bremner 1932, Loel and Corey 1932
	Dosinia margaritana	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Dosinia merriami	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Dosinia cf. *D. margaritana*	Y	Y	–	–	–	–	–	Shapiro 1998
	Glycymeris major	Y	–	–	–	–	–	–	Rand 1931
	Glycymeris sp.	Y	Y	–	–	–	–	–	Doerner 1969, Shapiro 1998
	Gryphaea sp.	–	Y	–	–	–	–	–	Bremner 1932
	Laevicardium sp.	Y	–	–	–	–	–	–	Shapiro 1998
	Lucina sp.	Y	–	–	–	–	–	–	Rand 1933
	Lyropecten crassicardo	–	–	–	–	–	–	Y	Bereskin and Edwards 1969, Weaver et al. 1969b, Fisher and Charlton 1976, Smith 1991, Shapiro 1998
	Lyropecten miguelensis	–	–	–	–	Y	Y	Y	Rand 1931, Bremner 1932, Loel and Corey 1932, Bereskin and Edwards 1969, Weaver et al. 1969b, Smith 1991, Shapiro 1998
	Lyropecten pretiosus	–	–	–	–	Y	–	–	Loel and Corey 1932, Bereskin and Edwards 1969, Smith 1991, Shapiro 1998
	Lyropecten vaughani	–	–	–	–	Y	–	–	Shapiro 1998
	Lyropecten sp.	–	–	–	–	Y	–	–	Shapiro 1998
	Macoma nasuta	–	–	–	–	Y	–	–	Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Macoma* sp.	–	–	–	–	Y	–	–	Shapiro 1998
	Macrocallista sp.?	Y	–	–	–	–	–	–	Doerner 1969
	Metis cf. *M. alta*	–	–	–	–	Y	–	–	Loel and Corey 1932
	Metis sp.	–	–	–	–	–	Y	–	Bremner 1932
	Mytilus expansus	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Mytilus sp.?	–	–	–	–	–	–	Y	Bereskin and Edwards 1969, Shapiro 1998
	Ostrea eldridgei	–	–	–	–	Y	–	Y	Loel and Corey 1932, Shapiro 1998
	Ostrea eldridgei ynezana	–	–	–	–	Y	–	–	Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998
	Ostrea eldridgei n. subspecies?	–	–	–	–	–	Y	–	Bremner 1932
	Ostrea idriaensis	Y	Y	–	–	–	–	–	Shapiro 1998
	Ostrea cf. *O. aviculiformis*	–	Y	–	–	–	–	–	Shapiro 1998
	Ostrea cf. *O. idriaensis*	–	U	U	U	–	–	–	Rand 1931
	Ostrea cf. *O. vespertina*	–	–	–	–	–	–	Y	Shapiro 1998
	Ostrea sp.	Y	Y	–	–	–	Y	Y	Bremner 1932, Weaver et al. 1969b, Fisher and Charlton 1976, Shapiro 1998
	Ostrea sp. (reef-forming)	Y	Y	–	–	–	–	–	Doerner 1969
	Panope generosa	–	–	–	–	–	Y	–	Bremner 1932
	Panope cf. *P. generosa*	–	–	–	–	Y	–	–	Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998
	Pecten estrellanus	–	–	–	–	Y	–	–	Rand 1931
	Pecten lompocensis	–	–	–	–	Y	Y	Y	Bremner 1932, Weaver et al. 1969b, Fisher and Charlton 1976, Shapiro 1998
	Pecten peckhami	–	–	–	–	Y	–	–	Shapiro 1998
	Phacoides acutilineatus	–	–	–	–	Y	–	–	Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998
	Phacoides santaecrucis	–	–	–	–	Y	–	–	Loel and Corey 1932, Shapiro 1998

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Phacoides* cf. *P. nuttalli*	–	–	–	–	Y	–	–	Rand 1931
	Phacoides sp.	Y	–	–	–	–	–	–	Shapiro 1998
	Phygraea haleyi	Y	–	–	–	–	–	–	Hertlein 1933, Squires 2018
	Solen sp.	Y	–	–	–	–	–	–	Shapiro 1998
	Spisula aff. *S. hemphilla*	–	–	–	–	Y	–	–	Shapiro 1998
	Spisula sp.	–	–	–	–	Y	–	–	Shapiro 1998
	Spondylus perrini	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Tellina sp.	–	Y	–	–	–	–	–	Bremner 1932
	Trachycardium vaquerosensis	–	–	–	–	Y	Y	Y	Rand 1931, Bremner 1932, Bereskin and Edwards 1969, Weaver et al. 1969b, Fisher and Charlton 1976, Shapiro 1998
	Venericardia hornii subspecies	–	U	U	U	–	–	–	Rand 1931
	Venericardia cf. *V. hornii*	–	Y	–	–	–	–	–	Bremner 1932
	Venericardia sp.	–	Y	–	–	–	–	–	Shapiro 1998
	Venus virginiana	–	–	–	–	Y	–	–	Loel and Corey 1932
	Vertipecten bowersi	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Smith 1991
	Vertipecten cf. *V. bowersi*	–	–	–	–	Y	–	–	Shapiro 1998
	Yoldia sp.	–	–	–	–	Y	–	–	Shapiro 1998
	Unidentified clam	Y	–	–	–	–	–	–	Kies 1982
	Unidentified gryphaeid	Y	Y	–	–	–	–	–	Shapiro 1998
	Unidentified oyster	Y	Y	–	–	–	–	Y	Fisher and Charlton 1976, Kies 1982, Boles 1998, Dibblee and Ehrenspeck 1998, Shapiro 1998
	Unidentified pecten	Y	–	–	–	–	–	Y	Fisher and Charlton 1976, Kies 1982
	Bivalvia undetermined	–	Y	–	Y	–	–	–	Kies 1982, Shapiro 1998
Mollusca: Cephalopoda: Nautiloidea (nautiloids)	*Eutrephoceras* sp.	–	Y	–	–	–	–	–	Shapiro 1998

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Mollusca: Gastropoda (snails)	**Gastropoda overall**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
	Amaurellina (*Euspirocromium*) *clarki*	–	U	U	U	–	–	–	Rand 1931
	Ampullina sp.	Y	Y	–	–	–	–	–	Bremner 1932, Shapiro 1998
	Calliostoma augustinensis	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Calyptraea costellata	–	–	–	–	Y	–	–	Shapiro 1998
	Calyptraea filosa?	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Calyptraea cf. *C. calabasaensis*	Y	–	–	–	–	–	–	Rand 1933, Shapiro 1998
	Cancellaria sp.	–	–	–	–	–	Y	–	Bremner 1932, Addicott 1965
	Conus sp.	–	–	Y	–	Y	Y	–	Bremner 1932, Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998
	Corsania (*Januncia*) *janus*	Y	–	–	–	–	–	–	Squires and Saul 2002
	Crepidula princeps	–	–	–	–	Y	Y	–	Bremner 1932, Bereskin and Edwards 1969, Shapiro 1998
	Crepidula cf. *C. praerupta*	–	–	–	–	Y	–	–	Loel and Corey 1932, Shapiro 1998
	Cylichnina tantilla	–	U	U	U	–	–	–	Rand 1931
	Distorsio sp.	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Ectinochilus sp.	–	Y	–	–	–	–	–	Bremner 1932
	Euspira simiensis	Y	–	–	–	–	–	–	Shapiro 1998
	Ficus sp.	–	Y	–	–	–	–	–	Shapiro 1998
	Fissurella rixfordi	–	–	–	–	Y	–	–	Loel and Corey 1932
	Galeodea sp.	Y	Y	–	–	–	–	–	Bremner 1932
	Globularia hannibali	–	U	U	U	–	–	–	Rand 1931
	Mitra sp.	–	Y	–	–	–	–	–	Bremner 1932
	Mitra sp.?	–	Y	–	–	–	–	–	Shapiro 1998
	Nassarius churchi	–	–	–	–	Y	–	–	Loel and Corey 1932
	Nassarius sp.	–	–	–	–	Y	–	–	Shapiro 1998

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Mollusca: Gastropoda (snails) (continued)	*Natica obliqua*	–	–	Y	–	–	–	–	Shapiro 1998
	Neverita sp.	–	–	–	Y	–	–	–	Shapiro 1998
	Neverita spp.	Y	–	–	–	–	–	–	Shapiro 1998
	Polinices recluzianus andersoni	–	–	–	–	Y	–	–	Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998
	Polinices sp.	–	–	–	–	–	Y	–	Bremner 1932
	Polinices spp.	–	Y	–	–	–	–	–	Shapiro 1998
	Purpura milicentana	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Rapana vaquerosensis	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Rimella sp.	–	–	–	Y	–	–	–	Shapiro 1998
	Scaphander costata	–	Y	–	–	–	–	–	Bremner 1932
	Scaphander jugularis	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Scaphander cf. *S. jugularis*	–	–	–	–	Y	Y	–	Bremner 1932, Loel and Corey 1932
	Scelidotoma aldersoni	–	–	–	–	Y	–	–	Powell and Geiger 2019
	Scelidotoma cf. *S. aldersoni*	–	–	–	–	Y	–	–	Powell and Geiger 2019
	Sinum obliquum	–	–	Y	–	–	–	–	Shapiro 1998
	Spiroglyphus sp.	–	Y	–	–	–	–	–	Shapiro 1998
	Thais carrizoensis	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Trichotropis sp.?	Y	–	–	–	–	–	–	Shapiro 1998
	Tritonalia ynezana	–	–	–	–	Y	–	–	Loel and Corey 1932
	Tritonalia cf. *T. ynezana* n. sp.	–	–	–	–	–	Y	–	Bremner 1932
	Trophon n. sp.	–	–	–	–	–	Y	–	Bremner 1932
	Trophon sp.	–	Y	–	–	Y	–	–	Loel and Corey 1932, Shapiro 1998
	Trophon sp.?	–	–	–	–	Y	–	–	Bereskin and Edwards 1969
	Trophosycon ocoyana	–	–	–	–	Y	–	–	Shapiro 1998
	Turritella applini	–	U	U	U	–	–	–	Rand 1931

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Mollusca: Gastropoda (snails) (continued)	*Turritella inezana*	–	–	–	–	Y	–	–	Shapiro 1998
	Turritella infragranulata	Y	–	–	–	–	–	–	Rand 1931, Bremner 1932, Doerner 1969, Shapiro 1998
	Turritella infragranulata pachecoensis	Y	–	–	–	–	–	–	Rand 1931, Bremner 1932, Saul 1983, Shapiro 1998
	Turritella infragranulata pachecoensis reworked from Paleocene	–	–	–	–	RI	–	RI	Howell et al. 1976, Stuart 1976
	Turritella ocoyana	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Turritella ocoyana bosei	–	–	–	–	Y	Y	–	Bremner 1932, Loel and Corey 1932, Bereskin and Edwards 1969, Shapiro 1998
	Turritella temblorensis	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Turritella uvasana	–	Y	–	–	–	–	–	Shapiro 1998
	Turritella uvasana applini	–	Y	–	–	–	–	–	Bremner 1932
	Turritella variata	–	U	U	U	–	–	–	Rand 1931
	Turritella cf. *T. uvasana applini*	Y	–	–	–	–	–	–	Bremner 1932
	Turritella n. sp.	–	–	–	–	–	Y	–	Bremner 1932
	Turritella sp.	Y	Y	Y	–	–	–	–	Bremner 1932, Kies 1982, Shapiro 1998, Squires 2018
	Voluta martini	–	Y	–	–	–	–	–	Bremner 1932
	Gastropoda undetermined	Y	Y	–	–	Y	–	–	Bereskin and Edwards 1969, Kies 1982
Mollusca: Scaphopoda (tusk shells)	*Dentalium* sp.	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
Annelida (segmented worms)	Small sabellariid polychaete tubes	Y	Y	–	–	–	–	–	Shapiro 1998
	Large sabellariid polychaete tubes	Y	Y	–	–	–	–	–	Shapiro 1998
Arthropoda: Crustacea: Cirripedia (barnacles)	*Balanus* sp.	–	–	–	–	Y	–	Y	Loel and Corey 1932, Bereskin and Edwards 1969
	Tetraclita sp.	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998

Appendix Table A-3-b (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Arthropoda: Crustacea: Cirripedia (barnacles) (continued)	Cirripedia undetermined	–	–	–	–	Y	–	Y	Fisher and Charlton 1976, Shapiro 1998
Echinodermata: Echinoidea (sea urchins)	*Eucidaris* sp.?	–	Y	–	–	–	–	–	Shapiro 1998
	Kewia fairbanksi	–	–	–	–	Y	–	–	Bereskin and Edwards 1969, Shapiro 1998
Other invertebrates	Shell debris	–	Y	–	–	–	–	–	Kies 1982

Appendix Table A-3-c. Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tmbt	Tmsh	Qph	Q	Reference
Cnidaria: Anthozoa: Scleractinia (stony corals)	*Balanophyllia elegans*	–	–	–	Y	Pinter et al. 1998
Bryozoa (moss animals)	*Celleporina* sp.	–	–	–	Y	SDNHM
	Bryozoa undetermined	–	–	Y	–	Weaver and Meyer 1969
Mollusca	**Mollusca overall**	**Y**	**Y**	**Y**	**Y**	**–**
	Mollusca undetermined	–	–	Y	–	Weaver and Meyer 1969
Mollusca: Polyplacophora (chitons)	*Callistochiton crassicostatus*	–	–	–	Y	SDNHM
	Callistochiton palmulatus	–	–	–	Y	SDNHM
	Nuttallina sp.	–	–	–	Y	SDNHM
	Polyplacophora undetermined	–	–	–	Y	SDNHM
Mollusca: Bivalvia (clams, oysters, etc.)	**Bivalvia overall**	**Y**	**Y**	**Y**	**Y**	**–**
	Arca obispoana	–	Y	–	–	Rand 1931
	Cardita (*Venericardia*) *californica*	–	–	Y	–	Rand 1933, Weaver and Meyer 1969
	Chione sp.	Y	–	–	–	Bereskin and Edwards 1969
	Crassadoma gigantea	–	–	–	Y	SDNHM
	Cyclocardia ventricosa	–	–	–	Y	SDNHM
	Epilucina californica	–	–	Y	–	Weaver and Meyer 1969

Appendix Table A-3-c (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tmbt	Tmsh	Qph	Q	Reference
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Epilucina* sp.	–	–	–	Y	Muhs and Groves 2018
	Glans carpenteri	–	–	–	Y	SDNHM
	Glans sp.	–	–	–	Y	Muhs and Groves 2018
	Glycymeris grewingki?	–	–	Y	–	Weaver and Meyer 1969
	Glycymeris septentrionalis	–	–	Y	–	Bremner 1932
	Glycymeris subobsoleta	–	–	–	Y	SDNHM
	Glycymeris sp.	–	–	–	Y	SDNHM
	Haliotis spp.	–	–	–	Y	SDNHM
	Lucinisca nuttalli	–	–	–	Y	SDNHM
	Macoma sp.	–	–	Y	–	Weaver and Meyer 1969
	Mytilus californianus	–	–	–	Y	SDNHM
	Mytilus aff. *M. coalingensis*	–	–	Y	–	Weaver and Meyer 1969
	Mytilus sp.	–	–	–	Y	Muhs and Groves 2018
	Nutricola tantilla	–	–	–	Y	SDNHM
	Patinopecten healeyi	–	–	Y	–	Weaver and Meyer 1969
	Pecten bellus	–	–	Y	–	Weaver and Meyer 1969
	Pecten islandicus	–	–	Y	–	Weaver and Meyer 1969
	Pecten peckhami	–	Y	–	–	Rand 1931, Weaver and Meyer 1969
	Pododesmus macrochisma	–	–	Y	–	Weaver and Meyer 1969
	Saxidomus nuttalli	–	–	Y	Y	Weaver and Meyer 1969, SDNHM
	Solen sp.	–	–	–	Y	SDNHM
	Tresus nuttallii	–	–	–	Y	SDNHM
	Venericardia montereyana	–	Y	–	–	Rand 1931
	Mytilidae undetermined	–	–	–	Y	SDNHM
Mollusca: Gastropoda (snails)	**Gastropoda overall**	**–**	**Y**	**Y**	**Y**	**–**
	Acanthinucella spirata	–	–	–	Y	SDNHM

Appendix Table A-3-c (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tmbt	Tmsh	Qph	Q	Reference
Mollusca: Gastropoda (snails) (continued)	*Acmaea asmi*	–	–	–	Y	SDNHM
	Acmaea mitra	–	–	Y	Y	Weaver and Meyer 1969, SDNHM
	Acmaea sp.	–	–	–	Y	Muhs and Groves 2018
	Acteocina sp.	–	–	–	Y	SDNHM
	Alia carinata	–	–	–	Y	SDNHM
	Amphissa columbiana	–	–	–	Y	SDNHM
	Amphissa versicolor	–	–	–	Y	SDNHM
	Astraea sp.	–	–	–	Y	SDNHM
	Barbarofusus barbarensis	–	–	–	Y	SDNHM
	Californiconus californicus	–	–	–	Y	SDNHM
	Californiconus sp.	–	–	–	Y	Muhs and Groves 2018
	Callianax biplicata	–	–	Y	–	Bremner 1932, Weaver and Meyer 1969
	Callianax sp.	–	–	–	Y	Muhs and Groves 2018
	Calliostoma augustinensis	–	Y	–	–	Rand 1933, Weaver and Meyer 1969
	Calliostoma coalingense	–	–	–	Y	SDNHM
	Calyptraea sp.	–	–	–	Y	SDNHM
	Cantharus sp.	–	–	–	Y	SDNHM
	Cerithiopsis sp.	–	–	–	Y	SDNHM
	Chlorostoma funebralis	–	–	Y	–	Rand 1933, Weaver and Meyer 1969
	Chlorostoma sp.	–	–	–	Y	Muhs and Groves 2018
	Clathurella sp.	–	–	–	Y	SDNHM
	Crepidula aculeata	–	–	–	Y	SDNHM
	Crepidula adunca	–	–	–	Y	SDNHM
	Crepidula perforans	–	–	–	Y	SDNHM
	Crepidula sp.	–	–	–	Y	SDNHM
	Crepipatella lingulata	–	–	–	Y	SDNHM

Appendix Table A-3-c (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tmbt	Tmsh	Qph	Q	Reference
Mollusca: Gastropoda (snails) (continued)	*Diodora aspera*	–	–	–	Y	SDNHM
	Epitonium indianorum	–	–	–	Y	SDNHM
	Fissurella volcano	–	–	–	Y	SDNHM
	Fissurella sp.	–	–	–	Y	Muhs and Groves 2018
	Fusinus luteopictus	–	–	–	Y	SDNHM
	Fusinus sp.	–	–	–	Y	SDNHM
	Fusinus sp.?	–	–	Y	–	Bremner 1932
	Haliotis cracherodii	–	–	–	Y	SDNHM
	Haliotis fulgens	–	–	–	Y	SDNHM
	Haliotis rufescens	–	–	–	Y	SDNHM
	Haliotis sp.	–	–	–	Y	Muhs and Groves 2018
	Halistylus pupoideus	–	–	–	Y	SDNHM
	Helminthoglypta ayresiana	–	–	–	Y	Snyder 2000
	Helminthoglypta sp.	–	–	–	Y	Snyder 2000
	Hipponix antiquatus	–	–	–	Y	SDNHM
	Hipponix tumens	–	–	–	Y	SDNHM
	Homalopoma luridum	–	–	–	Y	SDNHM
	Homalopoma sp.	–	–	–	Y	SDNHM
	Leptothyra sp.	–	Y	–	–	Rand 1933, Weaver and Meyer 1969
	Littorina keenae	–	–	–	Y	SDNHM
	Littorina scutulata	–	–	–	Y	SDNHM
	Littorina sp.	–	–	–	Y	Muhs and Groves 2018
	Lottia limatula	–	–	–	Y	SDNHM
	Lottia pelta	–	–	–	Y	SDNHM
	Lottia scabra	–	–	–	Y	SDNHM
	Mediargo mediocris	–	–	–	Y	SDNHM

Appendix Table A-3-c (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tmbt	Tmsh	Qph	Q	Reference
Mollusca: Gastropoda (snails) (continued)	*Mitra idea*	–	–	–	Y	SDNHM
	Mitrella sp.	–	–	–	Y	SDNHM
	Nassarius mendicus	–	–	–	Y	SDNHM
	Nassarius sp.	–	Y	–	–	Rand 1933, Weaver and Meyer 1969
	Neostylidium eschrichtii	–	–	–	Y	SDNHM
	Norrisia norrisii	–	–	–	Y	SDNHM
	Ocenebra beta	–	–	–	Y	SDNHM
	Ocenebra foveolata	–	–	–	Y	SDNHM
	Ocinebrina lurida	–	–	Y	–	Rand 1933, Weaver and Meyer 1969
	Odostomia sp.	–	–	–	Y	SDNHM
	Opalia wroblewskyi	–	–	–	Y	SDNHM
	Ophiodermella sp.	–	–	–	Y	SDNHM
	Physa sp.	–	–	–	Y	Snyder 2000
	Pristiloma shepardae	–	–	–	Y	Snyder 2000
	Pseudomelatoma sp.	–	–	–	Y	SDNHM
	Purpura nuttalli	–	–	Y	–	Rand 1933, Weaver and Meyer 1969
	Rissoina coronadoensis	–	–	Y	–	Weaver and Meyer 1969
	Searlesia cf. *S. dira*	–	–	Y	–	Rand 1933, Weaver and Meyer 1969
	Serpulorbis sp.	–	–	–	Y	SDNHM
	Tegula montereyi	–	–	–	Y	SDNHM
	Thais trancosana	–	–	–	Y	SDNHM
	Thylacodes sp.	–	–	–	Y	Muhs and Groves 2018
	Buccinidae?	–	–	–	Y	SDNHM
	Undetermined terrestrial gastropods	–	–	Y	Y	Weaver and Meyer 1969
	Gastropoda undetermined	–	Y	–	–	Weaver and Meyer 1969

Appendix Table A-3-c (continued). Fossil invertebrate taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tmbt	Tmsh	Qph	Q	Reference
Arthropoda: Crustacea: Cirripedia (barnacles)	*Balanus cariosus*	–	–	Y	–	Weaver and Meyer 1969
	Balanus gregarius	–	–	–	Y	SDNHM
	Balanus sp.	Y	–	–	–	Bereskin and Edwards 1969
Arthropoda: Crustacea: Decapoda: Brachyura (crabs)	*Randallia ornata*	–	–	–	Y	SDNHM
Arthropoda: Crustacea: Ostracoda (seed shrimp)	Freshwater ostracodes	–	–	–	Y	Snyder 2000
Arthropoda: Diplopoda	Diplopod fragment	–	–	–	Y	Grant 2016
Arthropoda: Insecta	Melolonthinae undetermined	–	–	–	Y	Grant 2016
	Psocodea undetermined (contaminant?)	–	–	–	Y	Grant 2016
	Ptininae undetermined	–	–	–	Y	Grant 2016
	Undetermined insect fragments	–	–	–	Y	Grant 2016
Echinodermata: Echinoidea (sea urchins)	*Dendraster excentricus*	–	–	–	Y	SDNHM
	Dendraster aff. *D. diegoensis*	–	–	Y	–	Weaver and Meyer 1969
	Strongylocentrotus sp.	–	–	Y	–	Weaver and Meyer 1969
	Echinoidea undetermined	–	–	Y	–	Weaver and Meyer 1969
Other invertebrates	Shell coquina	–	–	Y	–	Rand 1931, Bremner 1932
	Undetermined tube	–	–	–	Y	SDNHM
	Unspecified shell	–	–	–	Y	Pinter et al. 1998

Appendix Table A-3-d. Fossil vertebrate taxa reported from Santa Cruz Island in stratigraphic context.

Group	Taxon	Tc	Tv	Tr	Tsc	Tmsh	Q	References
Chondrichthyes (cartilaginous fish)	*Isurus* sp.	–	Y	–	–	–	–	Shapiro 1998
	Ray teeth	Y	Y	–	–	–	–	Bereskin and Edwards 1969, Shapiro 1998
	Shark teeth	–	Y	–	–	–	–	Bereskin and Edwards 1969
Actinopterygii (ray-finned fish)	Ctenoid fish scales	–	–	Y	–	–	–	Shapiro 1998
	Fish scales and bones	–	–	–	–	Y	–	Weaver and Meyer 1969
Aves	*Phalacrocorax* sp.	–	–	–	–	–	Y	SDNHM
	Aves undetermined	–	–	–	–	–	Y	SDNHM
Mammalia	**Mammalia overall**	**–**	**Y**	**–**	**Y**	**Y**	**Y**	**–**
	Mammalia undetermined	–	–	–	–	–	Y	SDNHM
Mammalia: Carnivora	*Canis familiaris*	–	–	–	–	–	Y	Rick et al. 2008
	Enhydra lutris	–	–	–	–	–	Y	SDNHM
	Urocyon littoralis	–	–	–	–	–	Y	Rick et al. 2009
	Otariidae undetermined	–	–	–	–	–	Y	SDNHM
Mammalia: Proboscidea	*Mammuthus columbi*?	–	–	–	–	–	Y	Cushing et al. 1984
	Mammuthus exilis	–	–	–	–	–	Y	Semprebon et al. 2016
	Mammuthus sp.	–	–	–	–	–	Y	Pigati et al. 2017
Mammalia: Desmostylia	Undescribed desmostylian	–	–	–	–	Y	–	Barnes and Aranda-Manteca 1997, Domning and Barnes 2007
Mammalia: Cetacea	Mysticeti undetermined	–	–	–	–	–	Y	SDNHM
	Cetacea undetermined	–	–	–	Y	Y	–	Weaver and Meyer 1969
	Cetacea undetermined?	–	Y	–	–	–	–	Bereskin and Edwards 1969, Shapiro 1998
Other vertebrates	Small vertebrates	–	–	–	–	–	Y	Snyder 2000
	Vertebrata undetermined	–	Y	–	–	–	–	Bereskin and Edwards 1969, Shapiro 1998

Appendix Table A-3-e. Ichnofossils reported from Santa Cruz Island in stratigraphic context.

Group	Taxon	Tp	Tc	Tcd	Tv	Qma	Q	References
Invertebrate ichnofossils	*Ophiomorpha* sp.	–	–	–	–	–	Y	SDNHM
	Thalassinoides isp.	–	–	–	Y	–	–	Shapiro 1998
	Zoophycos sp.	–	Y	–	–	–	–	Kies 1982
	Clasts bored by pholadid bivalves	–	–	–	–	Y	–	Weaver and Meyer 1969
	General bioturbation	Y	Y	Y	–	–	–	Kies 1982
	Invertebrate burrows	Y	Y	–	–	–	–	Kies 1982
	Possible worm tubes	–	Y	–	–	–	–	Kies 1982
	Sponge borings in shells	–	–	–	–	–	Y	SDNHM
	Termite frass	–	–	–	–	–	Y	Grant 2016

Appendix Table A-3-f. Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera	**Foraminifera overall**	**Y**	**Y**	**Y**	**?**	**Y**	**Y**	**Y**	**Y**	**–**
	Alabamina wilcoxensis californica	–	–	Y	–	–	–	–	–	Doerner 1969
	Allomorphina macrostoma	–	Y	Y	–	Y	–	–	–	Doerner 1969
	Allomorphina paleocenica	–	–	Y	–	–	–	–	–	Doerner 1969
	Allomorphina trigona	–	–	Y	–	–	–	–	–	Doerner 1969
	Ammobaculites sp.	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Ammodiscoides sp.	–	–	Y	–	–	–	–	–	Doerner 1969
	Amphimorphina californica	–	–	Y	–	–	–	–	–	Doerner 1969
	Amphimorphina ignota	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Amphimorphina yazooensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Amphimorphina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Anomalina dorri aragonensis	–	Y	Y	–	–	–	–	–	Doerner 1969
	Anomalina garzaensis	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Anomalina regina*	–	Y	Y	–	–	–	–	–	Doerner 1969
	Anomalina umbonata	–	–	Y	–	–	–	–	–	Doerner 1969
	Anomalina sp. A	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Anomalina sp. B	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Anomalina sp. C	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Anomalina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Baggatella californica	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Baggina cancriformis	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Bathysiphon eocenicus	–	–	Y	–	Y	–	–	–	Doerner 1969
	Bathysiphon sp.	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Bifarina eleganta	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Bifarina nuttalli	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Bifarina vicksburgensis	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Bifarina sp.?	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bolivina advena	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Bolivina aragonensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Bolivina californica	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Bolivina crenulata	–	–	Y	–	–	–	–	–	Doerner 1969
	Bolivina floridana?	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Bolivina incrassata	–	Y	–	–	–	–	–	–	Doerner 1969
	Bolivina kleinpelli	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bolivina marginata	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Bolivina pisciformis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bolivina salinasensis	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Bolivina scabrata	–	–	Y	–	–	–	–	–	Doerner 1969
	Bulimina alazanensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Bulimina alligata*	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Bulimina callahani	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Bulimina carlsoni	–	–	Y	–	–	–	–	–	Doerner 1969
	Bulimina corrugata	–	–	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Bulimina curtissima	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina ?curtissima	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina elongata	–	–	Y	–	–	–	–	–	Doerner 1969
	Bulimina guayabalensis	–	–	Y	–	Y	–	–	–	Doerner 1969
	Bulimina jacksonensis welcomensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina jarvisi	–	–	Y	–	–	–	–	–	Doerner 1969
	Bulimina kugleri	–	–	Y	–	Y	–	–	–	Doerner 1969
	Bulimina macilenta	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina ovata	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina pupoides	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina ?pupoides	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina schencki	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina sculptilis	–	–	–	–	Y	–	–	–	Doerner 1969
	Bulimina sculptilis brevis	–	–	–	–	Y	–	–	–	Doerner 1969
	Bulimina stalacta	–	–	–	–	Y	–	–	–	Doerner 1969
	Bulimina truncanella	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina whitei	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina cf. *B. instabilis*	–	–	–	–	Y	–	–	–	Doerner 1969
	Bulimina aff. *B. pyrula*	–	–	Y	–	Y	–	–	–	Doerner 1969
	Bulimina cf. *B. reussi*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Bulimina cf. *B. semicostata*	–	–	Y	–	–	–	–	–	Doerner 1969
	Bulimina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Buliminella curta*	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Buliminella elegantissima	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Buliminella grata convoluta	–	–	Y	–	–	–	–	–	Doerner 1969
	Buliminella robertsi	–	–	Y	–	–	–	–	–	Doerner 1969
	Buliminella subfusiformis	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Buliminella cf. *B. kugleri*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Buliminella sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Cancris brongniartii?	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Cancris robusta?	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Cancris sagra	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Cancris sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Cassidulina crassa	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Cassidulina globosa	–	–	Y	–	Y	–	–	–	Doerner 1969
	Cassidulina subglobosa	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Cassidulina sp. A	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Cassidulina sp.?	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Chilostomella cylindroides	–	Y	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Chilostomella hadleyi	–	–	Y	–	Y	–	–	–	Doerner 1969
	Chilostomella ovoidea serrata	–	–	Y	–	–	–	–	–	Doerner 1969
	Chilostomella cf. *C. ovoidea*	–	–	Y	–	–	–	–	–	Doerner 1969
	Chilostomella sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Cibicides alleni	–	Y	Y	–	–	–	–	–	Doerner 1969
	Cibicides americanus	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Cibicides beatus	–	–	Y	–	–	–	–	–	Doerner 1969
	Cibicides cocoaensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Cibicides cushmani	–	Y	Y	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Cibicides floridanus*	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Cibicides fortunatus	–	–	Y	–	–	–	–	–	Doerner 1969
	Cibicides grimsdalei	–	Y	Y	–	–	–	–	–	Doerner 1969
	Cibicides hodgei	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Cibicides martinezensis	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Cibicides martinezensis malloryi	–	–	Y	–	–	–	–	–	Doerner 1969
	Cibicides ouachitaensis alhambrensis	–	–	Y	–	Y	–	–	–	Doerner 1969
	Cibicides pachyderma	–	Y	Y	–	–	–	–	–	Doerner 1969
	Cibicides pseudowuellerstorfi	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Cibicides relizensis	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Cibicides sandiegensis	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Cibicides spiropunctatus	–	–	Y	–	Y	–	–	–	Doerner 1969
	Cibicides stephensoni	–	Y	–	–	–	–	–	–	Doerner 1969
	Cibicides susanaensis	–	Y	Y	–	–	–	–	–	Doerner 1969
	Cibicides tallahattensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Cibicides whitei	–	–	Y	–	–	–	–	–	Doerner 1969
	Cibicides cf. *C. coalingensis*	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Cibicides cf. *C. praecursorius*	–	Y	Y	–	–	–	–	–	Doerner 1969
	Cibicides sp. A	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Cibicides sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Cibicides spp.	–	–	Y	–	Y	–	–	–	Doerner 1969
	Cibicidoides venezuelanus	–	–	Y	–	–	–	–	–	Doerner 1969
	Cibicidoides cf. *C. coalingensis*	–	Y	Y	–	–	–	–	–	Doerner 1969
	Cibicidoides cf. *C. venezuelanus*	–	Y	Y	–	–	–	–	–	Doerner 1969
	Cyclammina sp.	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Dentalina approximata	–	–	Y	–	Y	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Dentalina catenula*	Y	–	–	–	–	–	–	–	Doerner 1969
	Dentalina communis	–	–	Y	–	–	–	–	–	Doerner 1969
	Dentalina consobrina	–	–	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Dentalina ?consobrina	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Dentalina delicatula	–	–	Y	–	–	–	–	–	Doerner 1969
	Dentalina dusenburyi	–	–	Y	–	Y	–	–	–	Doerner 1969
	Dentalina eocenica	–	–	Y	–	–	–	–	–	Doerner 1969
	Dentalina gardnerae	–	–	Y	–	–	–	–	–	Doerner 1969
	Dentalina hexacostata	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Dentalina jacksonensis	–	Y	Y	–	?	–	–	–	Doerner 1969
	Dentalina kreyenhagenensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Dentalina mucronata	–	–	Y	–	–	–	–	–	Doerner 1969
	Dentalina pauperata	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Dentalina soluta	–	–	Y	–	Y	–	–	–	Doerner 1969
	Dentalina solvata	–	–	Y	–	–	–	–	–	Doerner 1969
	Dentalina spinosa ornatior	–	–	Y	–	Y	–	–	–	Doerner 1969
	Dentalina cf. *D. approximata*	–	Y	–	–	–	–	–	–	Doerner 1969
	Dentalina cf. *D. sherborni*	–	–	Y	–	–	–	–	–	Doerner 1969
	Dentalina sp. A	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Dentalina sp. B	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Dentalina sp.	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Discammina sp.?	–	Y	Y	–	–	–	–	–	Doerner 1969
	Discocyclina clarki	–	–	Y	–	–	–	–	–	Bremner 1932
	Discorbis ?assulata	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Discorbis baintoni	–	–	Y	–	–	–	–	–	Doerner 1969
	Discorbis coalingensis	–	–	Y	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Discorbis* sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Dorothia cubana	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Dorothia sp.?	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Eggerella elongata	–	–	–	–	Y	–	–	–	Doerner 1969
	Eggerella subconica	–	–	–	–	Y	–	–	–	Doerner 1969
	Ellipsonodosaria atlantisae hispidula	–	–	Y	–	–	–	–	–	Doerner 1969
	Ellipsonodosaria cocoaensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Ellipsonodosaria sp.	–	–	Y	–	–	–	–	–	Doerner 1969
	"*Ellipsonodosaria* sp. A"	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Elphidium californicum	–	–	Y	–	–	–	–	–	Doerner 1969
	Elphidium granti	–	–	–	–	–	Y	–	–	Bereskin and Edwards 1969
	Elphidium hughesi	–	–	–	–	–	Y	–	–	Bereskin and Edwards 1969
	Entosolenia cf. *E. apiculata*	–	–	Y	–	–	–	–	–	Doerner 1969
	Entosolenia cf. *C. laevigata*	–	–	Y	–	–	–	–	–	Doerner 1969
	Entosolenia cf. *C. orbignyana*	–	–	Y	–	–	–	–	–	Doerner 1969
	Entosolenia sp.	–	–	Y	–	–	–	–	–	Doerner 1969
	Eoglobigerina minutissima	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Epistomina helicella	–	–	Y	–	–	–	–	–	Doerner 1969
	Epistomina partschiana	–	–	Y	–	–	–	–	–	Doerner 1969
	Epistomina ?partschiana	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Epistominella relizensis	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Eponides elevatus	–	Y	–	–	–	–	–	–	Doerner 1969
	Eponides lodoensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Eponides lodoensis martini	–	?	Y	–	–	–	–	–	Doerner 1969
	Eponides mexicana	–	Y	Y	–	–	–	–	–	Doerner 1969
	Eponides tenera	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Eponides umbonata*	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Eponides cf. *E. lisbonensis*	–	–	Y	–	–	–	–	–	Doerner 1969
	Globigerina boweri	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globigerina bulloides	–	–	Y	–	–	–	Y	Y	Bereskin and Edwards 1969, Doerner 1969, Molesworth and Sloan 1998
	Globigerina concinna	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Globigerina decepta	–	Y	–	–	–	–	–	–	Doerner 1969
	Globigerina mckannai	–	Y	–	–	–	–	–	–	Doerner 1969
	Globigerina ouachitaensis	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Globigerina praebulloides	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Globigerina triloculinoides	–	Y	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Globigerina cf. *G. officinalis*	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Globigerina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globigerinatheka sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globigerinella micra	–	–	Y	–	–	–	–	–	Doerner 1969
	Globobulimina pacifica	–	Y	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Globorotalia angulata	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia aragonensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia aragonensis twisselmanni	–	–	Y	–	–	–	–	–	Doerner 1969
	Globorotalia aspensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Globorotalia broedermanni lodoensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Globorotalia californica	–	Y	–	–	–	–	–	–	Doerner 1969
	Globorotalia centralis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia cerroazulensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia compressa	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia crassata densa	–	Y	–	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Globorotalia formosa gracilis*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia increbescens	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia marksi	–	Y	–	–	–	–	–	–	Doerner 1969
	Globorotalia nicoli	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Globorotalia rex	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globorotalia aff. *G. esnaensis*	–	–	Y	–	–	–	–	–	Doerner 1969
	Globorotalia sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Globotruncana arca	Y	–	–	–	–	–	–	–	Doerner 1969, Weaver 1969b
	Globulina gibba globosa	–	–	Y	–	–	–	–	–	Doerner 1969
	Gonatosphaera eocenica	–	–	Y	–	–	–	–	–	Doerner 1969
	Guembelina cf. *G. wilcoxensis*	–	–	Y	–	–	–	–	–	Doerner 1969
	Guembelina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Guttulina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Gyroidina aequilateralis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Gyroidina condoni	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Gyroidina florealis	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Gyroidina guayabalensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Gyroidina orbicularis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Gyroidina orbicularis planata	–	–	Y	–	–	–	–	–	Doerner 1969
	Gyroidina soldanii	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Gyroidina soldanii octocamerata	–	–	Y	–	–	–	–	–	Doerner 1969
	Gyroidina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Haplophragmoides deflata	–	Y	?	–	–	–	–	–	Doerner 1969
	Haplophragmoides excavata	–	Y	–	–	–	–	–	–	Doerner 1969
	Haplophragmoides kirki	–	Y	Y	–	–	–	–	–	Doerner 1969
	Haplophragmoides obliquicameratus	–	–	Y	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Haplophragmoides* sp.	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Haplophragmoides sp.?	–	–	Y	–	–	–	–	–	Doerner 1969
	Hastigerina micra	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Hastigerina sp.?	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Hyperammina ?elongata	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Karreriella chapapotensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Karreriella sp.	–	–	Y	–	–	–	–	–	Doerner 1969
	Karreriella sp.?	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Lagena acuticosta	–	–	Y	–	–	–	–	–	Doerner 1969
	Lagena conscripta	–	–	Y	–	–	–	–	–	Doerner 1969
	Lagena costata	–	–	Y	–	–	–	–	–	Doerner 1969
	Lagena globosa?	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Lagena hexagona	–	–	Y	–	–	–	–	–	Doerner 1969
	Lagena vulgaris	–	–	Y	–	Y	–	–	–	Doerner 1969
	Lagena cf. *L. amphora*	–	–	Y	–	–	–	–	–	Doerner 1969
	Lagena cf. *L. laevis*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Lagena sp.	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Lamarckina paleocenica	–	Y	–	–	–	–	–	–	Doerner 1969
	Lenticulina cf. *L. convergens*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Lenticulina sp.	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Loxostomum applinae	–	–	Y	–	–	–	–	–	Doerner 1969
	Marginulina adunca	–	–	Y	–	–	–	–	–	Doerner 1969
	Marginulina subbullata	–	–	–	–	Y	–	–	–	Doerner 1969
	Marginulina cf. *M. grata*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Marginulina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Marginulina sp.?	–	–	?	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Marginulinopsis* sp.	–	–	Y	–	–	–	–	–	Doerner 1969
	Martinottiella cf. *M. petrosa*	–	Y	Y	–	–	–	–	–	Doerner 1969
	Nodogenerina advena	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Nodogenerina advena hughesi	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Nodogenerina cooperensis	–	–	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Nodogenerina kressenbergensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Nodogenerina lepidula	–	Y	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Nodogenerina aff. *N. sagrinensis*	–	Y	Y	–	–	–	–	–	Doerner 1969
	Nodogenerina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Nodosarella attenuata	–	–	Y	–	–	–	–	–	Doerner 1969
	Nodosarella ignota	–	–	Y	–	–	–	–	–	Doerner 1969
	Nodosaria arundinea	–	Y	Y	–	–	–	–	–	Doerner 1969
	Nodosaria chirana	–	–	–	–	Y	–	–	–	Doerner 1969
	Nodosaria clavaeformis	–	Y	Y	–	Y	–	–	–	Doerner 1969
	Nodosaria cocoaensis mexicana	–	Y	Y	–	–	–	–	–	Doerner 1969
	Nodosaria deliciae	–	–	Y	–	–	–	–	–	Doerner 1969
	Nodosaria ewaldi	–	–	Y	–	Y	–	–	–	Doerner 1969
	Nodosaria gyrata	–	–	Y	–	–	–	–	–	Doerner 1969
	Nodosaria latejugata	–	Y	Y	–	–	–	–	–	Doerner 1969
	Nodosaria longiscata	–	–	Y	–	–	–	Y	–	Molesworth and Sloan 1998
	Nodosaria parexilis	–	Y	Y	–	–	–	Y	Y	Doerner 1969
	Nodosaria pyrula	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Nodosaria velascoensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Nodosaria cf. *N. anomala*	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Nodosaria sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Nodosaria spp.	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Nonion costiferum*	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Nonion incisum kernensis	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Nonion mediocostatum	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Nonion micrum	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Nonion sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Nonionella hantkeni spissa	–	–	Y	–	–	–	–	–	Doerner 1969
	Nonionella jacksonensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Nonionella turgida	–	–	Y	–	–	–	–	–	Doerner 1969
	Nonionella sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Parrella culter midwayana	–	–	Y	–	–	–	–	–	Doerner 1969
	Parrella tenuicarinata	–	–	Y	–	–	–	–	–	Doerner 1969
	Planularia toddae	–	–	Y	–	–	–	–	–	Doerner 1969
	Planularia truncana	–	–	Y	–	–	–	–	–	Doerner 1969
	Planularia cf. *P. truncana*	–	–	Y	–	–	–	–	–	Doerner 1969
	Planularia sp.	–	–	Y	–	–	–	–	–	Doerner 1969
	Plectofrondicularia kerni	–	–	Y	–	–	–	–	–	Doerner 1969
	Plectofrondicularia miocenica	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Plectofrondicularia miocenica laimingi	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Plectofrondicularia vokesi	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Plectofrondicularia sp. A	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Plectofrondicularia sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Pleurostomella alazanensis cubensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Pleurostomella paleocenica	–	–	Y	–	–	–	–	–	Doerner 1969
	Polymorphina ovata	–	–	Y	–	–	–	–	–	Doerner 1969
	Pseudoglandulina conica	–	–	Y	–	–	–	–	–	Doerner 1969
	Pullenia eocenica	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Pullenia salisburyi*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Quadrimorphina advena	–	–	Y	–	–	–	–	–	Doerner 1969
	Quinqueloculina sp.?	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Reophax sp.?	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Rhabdammina eocenica	–	?	Y	–	Y	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Robulus alatolimbatus	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Robulus arcuatostriatus carolinianus	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Robulus articulatus texanus	–	Y	–	–	–	–	–	–	Doerner 1969
	Robulus inornatus	–	Y	Y	–	–	–	–	–	Doerner 1969
	Robulus mayi	–	–	Y	–	–	–	Y	Y	Bereskin and Edwards 1969, Molesworth and Sloan 1998
	Robulus midwayensis	–	Y	–	–	–	–	–	–	Doerner 1969
	Robulus pseudovortex	–	–	Y	–	–	–	–	–	Doerner 1969
	Robulus reedi	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Robulus turbinatus	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Robulus ulatisensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Robulus vortex	–	Y	Y	–	–	–	–	–	Doerner 1969
	Robulus welchi	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Robulus ?welchi	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Robulus cf. *R. deformis*	–	–	Y	–	–	–	–	–	Doerner 1969
	Robulus cf. *R. gyroscalprus*	–	Y	Y	–	–	–	–	–	Doerner 1969
	Robulus cf. *R. mayi*	–	–	Y	–	–	–	–	–	Doerner 1969
	Robulus cf. *R. simplex*	–	–	–	–	–	Y	Y	–	Bereskin and Edwards 1969
	Robulus cf. *R. terryi*	–	–	Y	–	–	–	–	–	Doerner 1969
	Robulus sp. B	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Robulus sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Saccammina* sp.	–	Y	–	–	–	–	–	–	Doerner 1969
	Saracenaria cf. *S. kellumi*	–	Y	–	–	–	–	–	–	Doerner 1969
	Silicosigmoilina californica	–	Y	Y	–	–	–	–	–	Doerner 1969
	Siphogenerina branneri	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Siphogenerina kleinpelli	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Siphonina wilcoxensis	–	Y	–	–	–	–	–	–	Doerner 1969
	Sphaeroidinella subdehiscens	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Spiroloculina cf. *S. lamposa*	–	–	Y	–	–	–	–	–	Doerner 1969
	Spiroloculina ?cf. *S. lamposa*	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Spiroloculina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Spiroplectammina gryzbowskii	–	Y	–	–	–	–	–	–	Doerner 1969
	Spiroplectammina cf. *S. scotti*	–	–	Y	–	–	–	–	–	Doerner 1969
	Spiroplectammina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Suggrunda sp.	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Textularia adalta	–	Y	Y	–	–	–	–	–	Doerner 1969
	Textularia sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Textularia?	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Trifarina advena californica	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Trifarina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Tritaxia aspera whitei	–	Y	Y	–	–	–	–	–	Doerner 1969
	Tritaxilina colei	–	–	Y	–	–	–	–	–	Doerner 1969
	Trochammina globigeriniformis	–	Y	–	–	–	–	–	–	Doerner 1969
	Truncorotaloides topilensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Uvigerina alabamensis	–	–	Y	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	*Uvigerina churchi*	–	–	Y	–	Y	–	–	–	Doerner 1969
	Uvigerina elongata	–	–	Y	–	–	–	–	–	Doerner 1969
	Uvigerina garzaensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Uvigerina lodoensis miriamae	–	–	Y	–	–	–	–	–	Doerner 1969, Molesworth and Sloan 1998
	Uvigerina cf. *U. wilcoxensis*	–	–	Y	–	–	–	–	–	Doerner 1969
	Uvigerina sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Uvigerinella californica	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Uvigerinella californica ornata	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Uvigerinella californica parva	–	–	–	–	–	Y	Y	Y	Bereskin and Edwards 1969
	Uvigerinella obesa	–	–	–	–	–	–	Y	Y	Bereskin and Edwards 1969
	Uvigerinella obesa impolita	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Vaginulinopsis asperuliformis	–	–	Y	–	–	–	–	–	Doerner 1969
	Vaginulinopsis mexicana nudicostata	–	Y	Y	–	–	–	–	–	Doerner 1969
	Valvulineria casitasensis	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Valvulineria indiscriminata	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Valvulineria jacksonensis welcomensis	–	–	–	–	Y	–	–	–	Doerner 1969
	Valvulineria ornata	–	–	–	–	–	–	–	Y	Bereskin and Edwards 1969
	Valvulineria tumeyensis	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Valvulineria cf. *V. californica obesa*	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Valvulineria sp. A	–	–	–	–	–	–	Y	–	Bereskin and Edwards 1969
	Valvulineria sp.	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998
	Verneuilina triangulata	–	Y	Y	–	–	–	–	–	Doerner 1969
	Vulvulina curta	–	–	?	–	–	–	–	–	Doerner 1969
	Globigerinina undifferentiated	–	–	Y	–	–	–	–	–	Molesworth and Sloan 1998

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Foraminifera (continued)	Foraminifera undetermined	Y	Y	Y	?	–	Y	Y	Y	Rand 1933, Doerner 1969, Weaver 1969b, Patet 1972, Howell et al. 1976, Kies 1982, Dibblee and Ehrenspeck 1998, Molesworth and Sloan 1998, Squires 2018
Coccolithophores (see comment about Kies 1982)	**Coccolithophores overall**	**–**	**Y**	**Y**	**–**	**Y**	**–**	**–**	**–**	**–**
	Braarudosphaera discula	–	–	Y	–	–	–	–	–	Doerner 1969
	C. cavus	–	Y	–	–	–	–	–	–	Kies 1982
	C. consactus	–	–	Y	–	–	–	–	–	Kies 1982
	C. eopelagicur	–	–	Y	–	–	–	–	–	Kies 1982
	C. floridanns	–	–	Y	–	–	–	–	–	Kies 1982
	C. formosa	–	Y	Y	–	Y	–	–	–	Kies 1982
	C. grandis/grapdis	–	–	Y	–	Y	–	–	–	Kies 1982
	C. nitescons	–	–	Y	–	–	–	–	–	Kies 1982
	C. pelagicus/pelagiens	–	Y	Y	–	–	–	–	–	Kies 1982
	C. solitus	–	–	–	–	Y	–	–	–	Kies 1982
	C. titus	–	–	–	–	Y	–	–	–	Kies 1982
	Campylosphaera eodela	–	–	Y	–	–	–	–	–	Kies 1982
	Chiasmolithus bidens	–	Y	Y	–	–	–	–	–	Kies 1982
	Chiphragmalithus cristatus	–	–	Y	–	–	–	–	–	Doerner 1969
	Clathrolithus ellipticus	–	–	Y	–	–	–	–	–	Doerner 1969
	Coccolithus carus	–	–	Y	–	–	–	–	–	Kies 1982
	Coccolithus crassus	–	–	Y	–	–	–	–	–	Doerner 1969, Kies 1982
	Coccolithus grandis	–	–	Y	–	–	–	–	–	Doerner 1969
	Coccolithus staurion	–	–	Y	–	–	–	–	–	Doerner 1969
	Cyclococcolithus gammation	–	–	Y	–	–	–	–	–	Doerner 1969
	D. barbadiensis	–	–	–	–	Y	–	–	–	Kies 1982
	D. binodosus	–	–	Y	–	–	–	–	–	Kies 1982

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Coccolithophores (continued) (see comment about Kies 1982)	*D. delicatus*	–	Y	Y	–	–	–	–	–	Kies 1982
	D. distinctus	–	–	–	–	Y	–	–	–	Kies 1982
	D. duocavus	–	–	–	–	Y	–	–	–	Kies 1982
	D. helianthus	–	–	Y	–	–	–	–	–	Kies 1982
	D. lenticularis	–	Y	–	–	–	–	–	–	Kies 1982
	D. multipura	–	–	Y	–	Y	–	–	–	Kies 1982
	D. panchulata	–	–	Y	–	–	–	–	–	Kies 1982
	D. pectinatus	–	–	–	–	Y	–	–	–	Kies 1982
	D. plana	–	–	Y	–	–	–	–	–	Kies 1982
	Discoaster barbadiensis	–	–	Y	–	–	–	–	–	Doerner 1969
	Discoaster diastypus	–	–	Y	–	–	–	–	–	Kies 1982
	Discoaster distinctus	–	–	Y	–	–	–	–	–	Doerner 1969
	Discoaster kuepperi	–	–	Y	–	–	–	–	–	Doerner 1969, Kies 1982
	Discoaster lodoensis	–	–	Y	–	–	–	–	–	Doerner 1969, Kies 1982
	Discoaster multiradiatus	–	?	Y	–	–	–	–	–	Kies 1982
	Discoaster nobilis	–	Y	Y	–	–	–	–	–	Kies 1982
	Discoaster nonaradiatus	–	–	Y	–	–	–	–	–	Doerner 1969
	Discoaster saipanensis	–	–	Y	–	–	–	–	–	Kies 1982
	Discoaster sublodoensis	–	–	Y	–	–	–	–	–	Doerner 1969, Kies 1982
	Discoaster sp.	–	Y	–	–	–	–	–	–	Kies and Abbott 1982
	Discolithus distinctus	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus duocavus	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus exilis	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus fimbriatus	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus panarium	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus planus	–	–	Y	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Coccolithophores (continued) (see comment about Kies 1982)	*Discolithus pulcher*	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus ramosus	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus solidus	–	–	Y	–	–	–	–	–	Doerner 1969
	Discolithus versus	–	–	Y	–	–	–	–	–	Doerner 1969
	E. disticha	–	–	Y	–	–	–	–	–	Kies 1982
	E. macellus	–	Y	Y	–	–	–	–	–	Kies 1982
	F. schaubi	–	?	–	–	–	–	–	–	Kies 1982
	F. tympaniformis	–	Y	?	–	–	–	–	–	Kies 1982
	H. lophota	–	–	–	–	Y	–	–	–	Kies 1982
	H. phota	–	–	Y	–	–	–	–	–	Kies 1982
	Helicosphaera seminulum	–	–	Y	–	Y	–	–	–	Kies 1982
	Helicosphaera seminulum lophota	–	–	Y	–	–	–	–	–	Doerner 1969
	Helicosphaera seminulum seminulum	–	–	Y	–	–	–	–	–	Doerner 1969
	Lophodolithus mochlophorus	–	–	Y	–	–	–	–	–	Doerner 1969
	Micrantholithus crenulatus	–	–	Y	–	–	–	–	–	Doerner 1969
	Micrantholithus flos	–	–	Y	–	–	–	–	–	Doerner 1969
	Micrantholithus vesper	–	–	Y	–	–	–	–	–	Doerner 1969
	Micrantholithus spp.	–	–	Y	–	–	–	–	–	Kies 1982
	N. chiastas	–	Y	Y	–	–	–	–	–	Kies 1982
	N. dubius	–	–	–	–	Y	–	–	–	Kies 1982
	R. crebra/creora	–	–	Y	–	Y	–	–	–	Kies 1982
	R. inflata	–	–	Y	–	–	–	–	–	Kies 1982
	R. samndorovi	–	–	–	–	Y	–	–	–	Kies 1982
	Rhabdolithus inflata	–	–	Y	–	–	–	–	–	Doerner 1969
	Rhabdolithus tenuis	–	–	Y	–	–	–	–	–	Doerner 1969
	Rhabdosphaera crebra	–	–	Y	–	–	–	–	–	Doerner 1969

Appendix Table A-3-f (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (pre-volcanics).

Group	Taxon	K	Tp	Tc	Tjv	Tcd	Tv	Tr	Tso	References
Coccolithophores (continued) (see comment about Kies 1982)	*Rhabdosphaera morionum*	–	–	Y	–	–	–	–	–	Doerner 1969
	Rhabdosphaera perlonga	–	–	Y	–	–	–	–	–	Doerner 1969
	S. radians	–	–	Y	–	–	–	–	–	Kies 1982
	S. springer	–	–	Y	–	Y	–	–	–	Kies 1982
	Sphenolithus radians	–	–	Y	–	–	–	–	–	Doerner 1969
	T. palcher/polcher	–	–	Y	–	–	–	–	–	Kies 1982
	Toweius spp.	–	Y	Y	–	–	–	–	–	Kies 1982
	Tribrachiatus contortus	–	–	Y	–	–	–	–	–	Kies 1982
	Z. bijugatus/gijugatos	–	–	Y	–	Y	–	–	–	Kies 1982
	Zygodiscus plectopons	–	Y	Y	–	–	–	–	–	Kies 1982
	Undetermined coccoliths	–	Y	Y	–	Y	–	–	–	Kies 1982, Kies and Abbott 1982
Other fossils	Reworked fossiliferous Eocene boulders	–	–	–	–	–	RI	–	–	Rand 1931
	Unspecified "Temblor" fossils	–	–	–	–	–	–	Y	–	Rand 1931
	Undetermined fossils	–	Y	Y	–	–	Y	–	–	Bremner 1932, Kies 1982

Appendix Table A-3-g. Other fossil taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tsc	Tmbt	Tmsh	Tb	Qph	Q	Reference
Foraminifera	**Foraminifera overall**	**Y**	**Y**	**Y**	**–**	**Y**	**Y**	**–**
	Anomalina salinasensis	–	–	Y	–	–	–	Weaver and Meyer 1969
	Baggina californica	–	–	Y	–	–	–	Weaver and Meyer 1969
	Baggina cancriformis	–	–	Y	–	–	–	Weaver and Meyer 1969
	Baggina robusta	–	–	Y	–	–	–	Weaver and Meyer 1969
	Bathysiphon sp.	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Bolivina advena	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969

Appendix Table A-3-g (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tsc	Tmbt	Tmsh	Tb	Qph	Q	Reference
Foraminifera (continued)	*Bolivina advena*?	–	–	Y	–	–	–	Weaver and Meyer 1969
	Bolivina advena striatella	–	–	Y	–	–	–	Weaver and Meyer 1969
	Bolivina advena striatella?	–	–	Y	–	–	–	Weaver and Meyer 1969
	Bolivina brevior	–	–	Y	–	–	–	Weaver and Meyer 1969
	Bolivina californica	–	Y	Y	–	–	–	Bereskin and Edwards 1969
	Bolivina californica?	–	–	Y	–	–	–	Weaver and Meyer 1969
	Bolivina decurtata	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Bolivina floridana?	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Bolivina imbricata	–	–	Y	–	–	–	Weaver and Meyer 1969
	Bolivina marginata	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Bolivina subadvena spissa?	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Buccella mansfieldi	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Bulimina alligata	–	Y	–	–	–	–	Bereskin and Edwards 1969, Howell and McLean 1976
	Bulimina ovata	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Bulimina pseudotorta	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Buliminella californica?	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Buliminella curta	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Buliminella subfusiformis	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969, Howell and McLean 1976
	Cancris californica	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cassidulina crassa	–	–	Y	–	–	–	Weaver and Meyer 1969
	Cassidulina laevigata carinata	–	–	Y	–	–	–	Weaver and Meyer 1969
	Cassidulina panzana	–	–	Y	–	–	–	Weaver and Meyer 1969
	Cassidulina subglobosa	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cassidulina cf. *C. margareta*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cassidulina sp. B	–	Y	–	–	–	–	Bereskin and Edwards 1969

Appendix Table A-3-g (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tsc	Tmbt	Tmsh	Tb	Qph	Q	Reference
Foraminifera (continued)	*Chilostomella ovoidea*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cibicides americanus	–	Y	–	–	–	–	Bereskin and Edwards 1969, Howell and McLean 1976
	Cibicides floridanus	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cibicides aff. *C. floridanus*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cibicides cf. *C. illingi*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cibicides sp. B	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Cibicidoides sp.?	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Dentalina obliqua	–	–	Y	–	–	–	Weaver and Meyer 1969
	Dentalina sp. A	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Discorbis sp.	–	–	–	–	Y	–	Bremner 1932
	Dorothia sp.?	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Elphidium granti	–	Y	–	–	–	–	Howell and McLean 1976
	Elphidium cf. *E. granti*	–	–	Y	–	–	–	Weaver and Meyer 1969
	Elphidium sp.	–	–	Y	–	Y	Y	Weaver and Meyer 1969, SDNHM
	“Eoglobigerina” *minutissima*	–	–	Y	–	–	–	Weaver and Meyer 1969
	Epistominella relizensis	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Epistominella smithi	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Epistominella? cf. *E. subperuviana*	–	–	Y	–	–	–	Weaver and Meyer 1969
	Eponides keenani	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Eponides tenera	–	Y	–	–	–	–	Bereskin and Edwards 1969, Howell and McLean 1976
	Eponides cf. *E. multicameratus*	–	–	Y	–	–	–	Weaver and Meyer 1969
	Eponides sp. A	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Eponides sp. B	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Eponides sp. C	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Gaudryina sp.	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Glandulina laevigata	–	Y	–	–	–	–	Bereskin and Edwards 1969

Appendix Table A-3-g (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tsc	Tmbt	Tmsh	Tb	Qph	Q	Reference
Foraminifera (continued)	*Globigerina angustiumbilicata*	–	–	Y	–	–	–	Weaver and Meyer 1969
	Globigerina bulloides	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Globigerina connecta	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Globigerina praebulloides	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Globigerinita glutinata	–	–	Y	–	–	–	Weaver and Meyer 1969
	Globobulimina pacifica	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Gyroidina soldanii	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Gyroidina soldanii cf. *G. s. rotundimargo*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Haplophragmoides sp.	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Nodogenerina advena	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Nodogenerina advena hughesi	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Nodogenerina sp. A	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Nodosaria longiscata	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Nodosaria parexilis	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Nodosaria cf. *N. anomala*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Nodosaria spp.	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Nonion costiferum	–	Y	Y	–	–	–	Rand 1931, Kleinpell 1938, Bereskin and Edwards 1969, Weaver and Meyer 1969
	Nonion mediocostatum	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Planulina cf. *P. ariminensis*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Plectofrondicularia californica	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Pullenia miocenica	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Pullenia miocenica globula	–	–	Y	–	–	–	Weaver and Meyer 1969
	Robulus sp. A	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Robulus sp. B	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Siphogenerina branneri	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969

Appendix Table A-3-g (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tsc	Tmbt	Tmsh	Tb	Qph	Q	Reference
Foraminifera (continued)	*Siphogenerina kleinpelli*	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969, Howell and McLean 1976
	Siphogenerina nuciformis	–	–	Y	–	–	–	Rand 1931, Kleinpell 1938, Weaver and Meyer 1969
	Siphogenerina reedi	–	–	Y	–	–	–	Weaver and Meyer 1969
	Siphogenerina aff. *S. nuciformis*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Textularia sp.?	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Uvigerinella californica	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Uvigerinella californica ornata	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Uvigerinella californica parva	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Uvigerinella obesa	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969
	Uvigerinella obesa impolita	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Uvigerinella aff. *U. obesa*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Valvulineria californica	–	–	Y	–	–	–	Rand 1931, Kleinpell 1938
	Valvulineria californica appressa	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria californica californica	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria californica californica?	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria californica obesa	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria depressa	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria miocenica	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria miocenica?	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria ornata	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Valvulineria ornata?	–	–	Y	–	–	–	Weaver and Meyer 1969
	Valvulineria cf. *V. californica obesa*	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Valvulineria sp. A	–	Y	–	–	–	–	Bereskin and Edwards 1969
	Virgulina californiensis	–	–	Y	–	–	–	Weaver and Meyer 1969
	Virgulina sp.?	–	Y	Y	–	–	–	Bereskin and Edwards 1969, Weaver and Meyer 1969

Appendix Table A-3-g (continued). Other fossil taxa reported from Santa Cruz Island in stratigraphic context (post-volcanics).

Group	Taxon	Tsc	Tmbt	Tmsh	Tb	Qph	Q	Reference
Foraminifera (continued)	Foraminifera undetermined	Y	–	Y	–	Y	Y	Bremner 1932, Nolf and Nolf 1969, Weaver and Meyer 1969, SDNHM
Bacillariophyceae (diatoms)	Bacillariophyceae undetermined	–	–	Y	–	–	–	Rand 1931, Weaver and Meyer 1969
Other fossils	Fungal mycorrhizae, vesicular-arbuscular	–	–	–	–	–	Y	Anderson et al. unpublished data
	Fungal sclerotia	–	–	–	–	–	Y	Scott et al. 2010
	Unspecified "algae"	–	–	–	–	Y	–	Weaver and Meyer 1969
	Unspecified macrofossils	–	–	–	?	–	–	Fisher and Charlton 1976, Howell and McLean 1976, McLean et al. 1976b

Anacapa Island Records

Unlike the three previous islands, essentially all of the records for Anacapa Island are of Pleistocene fossils. The only exceptions are undetermined Miocene gastropods mentioned in Scholl (1959). Therefore, there are no stratigraphic columns in the following tables (Appendix Table A-4-a for fossil invertebrates and Appendix Table A-4-b for all other taxa). Records noted nowhere else but in the collections of the San Diego Natural History Museum have "SDNHM" in "References".

Appendix Table A-4-a. Pleistocene fossil invertebrate taxa reported from Anacapa Island.

Group	Taxon	References
Bryozoa (moss animals)	*Cellaria* sp.	SDNHM
	Celleporina sp.	SDNHM
	Lagenicella punctulata	SDNHM
	Cheilostomata undetermined	SDNHM
Mollusca: Polyplacophora (chitons)	*Amicula stelleri*	Valentine and Lipps 1963
	Cyanoplax lowei	Valentine and Lipps 1963
	Mopalia muscosa	Valentine and Lipps 1963, Lipps 1964
	Stenoplax heathiana	Valentine and Lipps 1963
	Tonicella lineata	Valentine and Lipps 1963
	Polyplacophora undetermined	Lipps 1964, Muhs and Groves 2018
Mollusca: Bivalvia (clams, oysters, etc.)	*Arca sisquocensis*	Valentine and Lipps 1963
	Bernardina bakeri	Valentine and Lipps 1963
	Chaceia ovoidea	SDNHM
	Chione californiensis	Lipps 1964, Muhs and Groves 2018
	Chlamys sp.	Muhs and Groves 2018
	Crassadoma gigantea	Lipps 1964, Muhs and Groves 2018
	Crassadoma sp.	SDNHM
	Crenella divaricata	Valentine and Lipps 1963
	Cumingia californica	Valentine and Lipps 1963
	Cyclocardia ventricosa	SDNHM
	Epilucina californica	Valentine and Lipps 1963, Muhs and Groves 2018
	Glans carpenteri	Valentine and Lipps 1963
	Glycymeris subobsoleta	Valentine and Lipps 1963
	Glycymeris sp.	SDNHM
	Irus lamellifer	Valentine and Lipps 1963
	Irus sp.	SDNHM
	Lasaea cistula	Valentine and Lipps 1963
	Leopecten diegensis	Muhs and Groves 2018
	Leukoma sp.	Muhs and Groves 2018
	Lima sp.	Valentine and Lipps 1963

Appendix Table A-4-a (continued). Pleistocene fossil invertebrate taxa reported from Anacapa Island.

Group	Taxon	References
Mollusca: Bivalvia (clams, oysters, etc.) (continued)	*Macoma nasuta*	Valentine and Lipps 1963
	Modiolus sp.	SDNHM
	Modiolus sp.?	Valentine and Lipps 1963
	Mysella tumida	SDNHM
	Mysella aff. *M. tumida*	Valentine and Lipps 1963
	Mytilus californianus	Valentine and Lipps 1963, Muhs and Groves 2018
	Nutricola tantilla	Valentine and Lipps 1963
	Ostrea lurida	Muhs and Groves 2018
	Parvilucina sp.	SDNHM
	"Pecten" sp.	Valentine and Lipps 1963
	Philobrya setosa	SDNHM
	Pododesmus macrochisma	Valentine and Lipps 1963
	Protothaca staminea	Valentine and Lipps 1963
	Pseudochama exogyra	Muhs and Groves 2018
	Saxicava cf. *S. arctica*	Valentine and Lipps 1963
	Saxidomus nuttalli	Valentine and Lipps 1963
	Saxidomus sp.	Muhs and Groves 2018
	Semele quentinensis	Valentine and Lipps 1963
	Septifer bifurcatus	Valentine and Lipps 1963
	Tellina salmonea	Valentine and Lipps 1963
	Tellina sp.	Valentine and Lipps 1963
	Trachycardium quadragenarium	Muhs and Groves 2018
	Trachycardium cf. *T. quadragenarium*	Lipps 1964
	Tresus nuttallii	Muhs and Groves 2018
	Turtonia minuta	Valentine and Lipps 1963
	Veneridae undetermined	SDNHM
	Pelecypoda undetermined	SDNHM
Mollusca: Gastropoda (snails)	*Acanthinucella punctulata*	Valentine and Lipps 1963
	Acanthinucella spirata	SDNHM
	Acmaea asmi	SDNHM
	Acmaea digitalis	Valentine and Lipps 1963
	Acmaea mitra	Muhs and Groves 2018
	Acmaea cf. *A. scutum*	Valentine and Lipps 1963
	Acmaea sp.	Lipps 1964
	Acteocina culcitella	Valentine and Lipps 1963
	Alia carinata	Valentine and Lipps 1963, Muhs and Groves 2018

Appendix Table A-4-a (continued). Pleistocene fossil invertebrate taxa reported from Anacapa Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Alvania compacta*	SDNHM
	Alvania cosmia	SDNHM
	Alvania purpurea	Valentine and Lipps 1963
	Alvania rosana	Valentine and Lipps 1963
	Amphissa columbiana	Valentine and Lipps 1963
	Amphissa versicolor	Muhs and Groves 2018
	Amphissa? cf. *A. versicolor*	Valentine and Lipps 1963
	Amphissa sp.	Muhs and Groves 2018
	Amphithalamus tenuis	Valentine and Lipps 1963
	Amphithalamus sp.	SDNHM
	Antisabia panamensis	Muhs and Groves 2018
	Barbarofusus arnoldi	Valentine and Lipps 1963
	Barleeia haliotiphila	Valentine and Lipps 1963, Muhs and Groves 2018
	Barleeia cf. *B. haliotiphila*	Valentine and Lipps 1963
	Barleeia cf. *B. oldroydi*	Valentine and Lipps 1963
	Barleeia sp.	SDNHM
	Bittium armillatum	Valentine and Lipps 1963
	Bittium purpureum	SDNHM
	Caecum californicum	Valentine and Lipps 1963, Muhs and Groves 2018
	Caecum dalli	Valentine and Lipps 1963
	Caecum orcutti	Valentine and Lipps 1963
	Calicantharus fortis	Valentine and Lipps 1963
	Californiconus californicus	Valentine and Lipps 1963, Lipps 1964, Muhs and Groves 2018
	Callianax biplicata	Valentine and Lipps 1963, Kern et al. 1974, Muhs and Groves 2018
	Calliostoma doliarium	Valentine and Lipps 1963
	Calliostoma aff. *C. grantianum*	Valentine and Lipps 1963
	Calliostoma ligatum	Valentine and Lipps 1963
	Cantharus sp.	SDNHM
	Cerithiopsis cf. *C. antefilosa*	Valentine and Lipps 1963
	Cerithiopsis sp.	Valentine and Lipps 1963
	Clathurella cymodoce	Valentine and Lipps 1963
	Chlorostoma brunnea	SDNHM
	Chlorostoma funebralis	Valentine and Lipps 1963
	Chlorostoma gallina	Muhs and Groves 2018

Appendix Table A-4-a (continued). Pleistocene fossil invertebrate taxa reported from Anacapa Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Clio* sp.	Valentine and Lipps 1963
	Crepidula aculeata	Valentine and Lipps 1963
	Crepidula adunca	Valentine and Lipps 1963
	Crepidula onyx	Valentine and Lipps 1963
	Crepidula nummaria	Valentine and Lipps 1963
	Crepidula perforans	Muhs and Groves 2018
	Crepidula cf. *nivea*	Valentine and Lipps 1963
	Crepidula sp.	Muhs and Groves 2018
	Crepidula spp.	SDNHM
	Crepipatella lingulata	Valentine and Lipps 1963
	Crossata californica	Muhs and Groves 2018
	Cystiscus jewetti	Valentine and Lipps 1963
	Cystiscus politus	SDNHM
	Cystiscus regularis	Valentine and Lipps 1963
	Cynthia? cf. *C. albida*	Valentine and Lipps 1963
	Diodora aspera	Valentine and Lipps 1963
	Discurria insessa	Valentine and Lipps 1963, Muhs and Groves 2018
	Discurria insessa subspecies	Valentine and Lipps 1963
	Fartulum orcutti	Valentine and Lipps 1963
	Fissurella volcano	Muhs and Groves 2018
	Fusinus kobelti	SDNHM
	Fusinus sp.	SDNHM
	Gibberulina pyriformis	Valentine and Lipps 1963
	Granulina margaritula	SDNHM
	Haliotis cracherodii	Muhs and Groves 2018
	Haliotis rufescens	Valentine and Lipps 1963, Muhs and Groves 2018
	Haliotis cf. *H. cracherodii*	Lipps 1964
	Haliotis sp.	Valentine and Lipps 1963, Muhs and Groves 2018
	Harfordia kobelti	Muhs and Groves 2018
	Helminthoglypta ayresiana	Lipps 1964
	Hipponix antiquatus	Valentine and Lipps 1963
	Hipponix tumens	Valentine and Lipps 1963, Lipps 1964, Muhs and Groves 2018
	Homalopoma luridum	Valentine and Lipps 1963
	Lacuna carinata	SDNHM

Appendix Table A-4-a (continued). Pleistocene fossil invertebrate taxa reported from Anacapa Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Lacuna unifasciata*	SDNHM
	Lacuna cf. *L. carinata*	Valentine and Lipps 1963
	Lacuna cf. *L. unifasciata*	Valentine and Lipps 1963
	Lamellaria rhombica	Valentine and Lipps 1963
	Lirobittium attenuatum	Valentine and Lipps 1963
	Lirobittium sp.	Muhs and Groves 2018
	Lirularia sp.	SDNHM
	Littorina planaxis	Valentine and Lipps 1963
	Littorina scutulata	Valentine and Lipps 1963
	Littorina sp.	Muhs and Groves 2018
	Lottia limatula	Valentine and Lipps 1963
	Lottia pelta	Valentine and Lipps 1963, Lipps 1964
	Lottia scabra	Valentine and Lipps 1963, Lipps 1964, Muhs and Groves 2018
	Lottia spp.	Muhs and Groves 2018
	Mangelia cf. *M. interlirata*	Valentine and Lipps 1963
	Mangelia sp.	Valentine and Lipps 1963
	Margarites cf. *M. optabilis*	Valentine and Lipps 1963
	Megatebennus bimaculatus	Valentine and Lipps 1963
	Melanella cf. *M. micans*	Valentine and Lipps 1963
	Micranellum crebricinctum	Valentine and Lipps 1963
	Mexacanthina lugubris	Muhs and Groves 2018
	Mitra idae	Muhs and Groves 2018
	Mitrella tuberosa	Valentine and Lipps 1963
	Mitromorpha barbarensis	Valentine and Lipps 1963
	Mitromorpha gracilior	Valentine and Lipps 1963
	“*Nassa*” *perpinguis*	Valentine and Lipps 1963
	Nassarius mendicus	Muhs and Groves 2018
	Neobernaya spadicea	Muhs and Groves 2018
	Neostylidium eschrichtii	SDNHM
	Neostylidium eschrichtii montereyense	Valentine and Lipps 1963
	Ocenebra beta	SDNHM
	Ocenebra circumtexta	SDNHM
	Ocenebra foveolata	Valentine and Lipps 1963
	Ocenebra interfossa	Valentine and Lipps 1963
	Ocenebra interfossa cf. *O. i. beta*	Valentine and Lipps 1963
	Ocenebra interfossa keepi	Valentine and Lipps 1963

Appendix Table A-4-a (continued). Pleistocene fossil invertebrate taxa reported from Anacapa Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Ocenebra* sp.	SDNHM
	Ocinebrina sp.	Muhs and Groves 2018
	Odostomia virginalis	SDNHM
	Odostomia cf. *O. domilla*	Valentine and Lipps 1963
	Odostomia cf. *O. phanea*	Valentine and Lipps 1963
	Odostomia cf. *O. virginalis*	Valentine and Lipps 1963
	Odostomia sp.	Valentine and Lipps 1963
	Petaloconchus complicatus	Valentine and Lipps 1963
	Pseudomelatoma penicillata	SDNHM
	Pseudomelatoma torosa	Valentine and Lipps 1963
	Pterynotus festivus	Valentine and Lipps 1963
	Puncturella delosi	Valentine and Lipps 1963
	Puncturella sp.	SDNHM
	Tegula marcida	Valentine and Lipps 1963
	Tegula montereyi	Valentine and Lipps 1963
	Tegula pulligo	SDNHM
	Thylacodes squamigerus	Valentine and Lipps 1963, Lipps 1964, Muhs and Groves 2018
	Tricolia pulloides	Valentine and Lipps 1963
	Tricolia substriata	SDNHM
	Trimusculus reticulatus	Valentine and Lipps 1963
	Turbonilla laminata	SDNHM
	Turbonilla cf. *T. gouldi*	Valentine and Lipps 1963
	Turbonilla sp.	Valentine and Lipps 1963
	Turritella cooperi	Valentine and Lipps 1963
	Vitrinella eshnauri	Valentine and Lipps 1963
	Vitrinella oldroydi	SDNHM
	Williamia peltoides	SDNHM
	Gastropoda undetermined	SDNHM
Mollusca: Scaphopoda (tusk shells)	*Dentalium* cf. *D. pretiosum*	Valentine and Lipps 1963
Annelida (segmented worms)	Indeterminate polychaete tube	Muhs and Groves 2018
	Polychaeta undetermined	Muhs and Groves 2018
Arthropoda: Crustacea: Cirripedia (barnacles)	*Balanus* sp.	Lipps 1964
	Tetraclita sp.?	Valentine and Lipps 1963
	Thoracica undetermined	SDNHM
	Cirripedia undetermined	Valentine and Lipps 1963, Muhs and Groves 2018

Appendix Table A-4-a (continued). Pleistocene fossil invertebrate taxa reported from Anacapa Island.

Group	Taxon	References
Arthropoda: Crustacea: Decapoda: Brachyura (crabs)	*Cancer antennarius*	SDNHM
	Brachyura undetermined	Muhs and Groves 2018
Arthropoda: Crustacea: Ostracoda (seed shrimp)	Ostracoda undetermined	SDNHM
Arthropoda: Insecta: Coleoptera (beetles)	*Eleodes* sp. (possibly modern contaminant)	Lipps 1964
Echinodermata: Echinoidea (sea urchins)	*Dendraster venturaensis*	Valentine and Lipps 1963
	Dendraster sp.	SDNHM
	Strongylocentrotus sp.?	Valentine and Lipps 1963
	Echinoidea undetermined	Lipps 1964, Muhs and Groves 2018
Other invertebrates	Undetermined shells	Lipps 1964

Appendix Table A-4-b. Other Pleistocene fossil taxa reported from Anacapa Island.

Group	Taxon	References
Actinopterygii (ray-finned fish)	*Pimelometopon pulchrum*	Lipps 1964
	Actinopterygii undetermined	Muhs and Groves 2018
Aves	Aves undetermined	Valentine and Lipps 1963, Muhs and Groves 2018
Aves: Procellariiformes (petrels)	*Oceanodroma leucorhoa kaedingi*	Lipps 1964
	Puffinus griseus	Lipps 1964
Aves: Suliformes (gannets and cormorants)	*Phalacrocorax penicillatus*	Lipps 1964
Aves: Anseriformes (ducks and geese)	*Chendytes lawi*	Miller et al. 1961, Howard 1964a, Lipps 1964, Guthrie 1998, Jones et al. 2008
Aves: Cathartiformes (New World vultures)	*Gymnogyps amplus*?	Lipps 1964
Aves: Charadriiformes (gulls, waders, etc.)	*Fratercula dowi*	Lipps 1964, Guthrie et al. 1999
	Larus sp.	Lipps 1964
	Ptychoramphus aleuticus	Lipps 1964
	Synthliboramphus hypoleucus?	Lipps 1964
	Alcidae undetermined	Lipps 1964
Mammalia	Mammalia undetermined	Lipps 1964
Mammalia: Rodentia	*Peromyscus anyapahensis*	White 1966, Guthrie 1998, Knowlton et al. 2007
Other vertebrates	Undetermined fish bones	Valentine and Lipps 1963
	Vertebrata undetermined	Valentine and Lipps 1963
Invertebrate ichnofossils	*Helicotaphrichnus commensalis*	Kern et al. 1974
	Sponge borings on shell	SDNHM

Appendix Table A-4-b (continued). Other Pleistocene fossil taxa reported from Anacapa Island.

Group	Taxon	References
Foraminifera	*Elphidium fax*	Scholl 1960, Valentine and Lipps 1963
	Elphidium granulosum	Scholl 1960, Valentine and Lipps 1963
	Elphidium sp.	SDNHM
	Foraminifera undetermined	SDNHM

Santa Barbara Island Records

As with Anacapa Island, virtually all records from Santa Barbara Island are of Quaternary age, so the tables below are of Quaternary taxa only (Appendix Table A-5-a for plants, A-5-b for invertebrates, A-5-c for vertebrates, and A-5-d for ichnofossils and other taxa). Miocene records are limited to a handful of foraminifera taxa reported in Kemnitzer (1933). They are: *Baggina robusta*, *Bolivina* cf. *B. floridana*, *Cancris* sp., *Valvulineria californica obesa*, *Valvulineria californica opressa*, and undetermined foraminifera.

Lipps et al. (1968) reported that the foraminifera they found included reworked Miocene forms, but did not indicate which were reworked, and none of the species appears to be limited to the Miocene, so it was not possible to determine which were reworked. Muhs et al. (2018) re-analyzed the Lipps et al. macrofossils, so any taxa attributed only to Lipps et al. (1968) may have been re-identified or may be junior synonyms of other taxa.

The taxa cited from Collins et al. (2018b) are all from the late Holocene; the oldest strata were selected to avoid historic levels, and include Unit 1A strata III/2, IV/1, IV/1, and V/1, and Unit 2 Stratum III/6.

Appendix Table A-5-a. Paleontological Quaternary plant taxa reported from Santa Barbara Island.

Group	Taxon	References
Magnoliophyta (flowering plants)	*Galium* spp.	Collins et al. 2018b
	Opuntia spp.	Collins et al. 2018b
	Poaceae undetermined	Collins et al. 2018b
Other plants	Undetermined plants	Collins et al. 2018b

Appendix Table A-5-b. Paleontological Quaternary invertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Cnidaria: Anthozoa: Scleractinia (stony corals)	*Balanophyllia elegans*	Muhs and Groves 2018 (includes undetermined corals of Lipps et al. 1968)
Mollusca	Mollusca undetermined	Collins et al. 2018b
Mollusca: Polyplacophora (chitons)	*Callistochiton crassicostatus*	Lipps et al. 1968
	Callistochiton palmulatus mirabilis	Lipps et al. 1968
	Callistochiton sp.	Muhs and Groves 2018
	Chaetopleura sp.	Muhs and Groves 2018
	Cryptochiton stelleri	Muhs and Groves 2018
	Cyanoplax lowei	Lipps et al. 1968
	Cyanoplax sp.	Muhs and Groves 2018
	Ischnochiton heathiana	Lipps et al. 1968
	Ischnochiton cf. *I. mertensii*	Lipps et al. 1968

Appendix Table A-5-b (continued). Paleontological Quaternary invertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Mollusca: Polyplacophora (chitons) (continued)	*Ischnochiton* sp.	Lipps et al. 1968, Muhs and Groves 2018
	Mopalia muscosa	Lipps et al. 1968
	Mopalia sp.	Muhs and Groves 2018
	Nuttallina californica	Lipps et al. 1968
	Nuttallina sp.	Muhs and Groves 2018
	Pallochiton lanuginosus	Lipps et al. 1968
	Polyplacophora undetermined	Collins et al. 2018b, Muhs and Groves 2018
Mollusca: Bivalvia (clams, oysters, etc.)	*Bernardina bakeri*	Lipps et al. 1968, Muhs and Groves 2018
	Chama arcana	Muhs and Groves 2018
	Cumingia californica	Muhs and Groves 2018
	Epilucina californica	Lipps et al. 1968, Muhs and Groves 2018
	Glans carpenteri	Lipps et al. 1968, Muhs and Groves 2018
	Grippina californica	Muhs and Groves 2018
	Grippina aff. *G. californica*	Lipps et al. 1968
	Lasaea adansoni	Muhs and Groves 2018
	Lasaea cistula	Lipps et al. 1968
	Lasaea subviridis	Lipps et al. 1968
	?*Nutricola* sp.	Muhs and Groves 2018
	Psephidia sp.?	Lipps et al. 1968
	Saxidomus sp.	Muhs and Groves 2018
	Semele sp.?	Lipps et al. 1968
	Septifer bifurcatus	Lipps et al. 1968, Muhs and Groves 2018
	Trachycardium cf. *T. quadragenarium*	Lipps et al. 1968
	?*Trachycardium* sp.	Muhs and Groves 2018
	Bivalvia undetermined	Muhs and Groves 2018
Mollusca: Cephalopoda: Coleoidea (squids, etc.)	Coleoidea undetermined	Collins et al. 2018b
Mollusca: Gastropoda (snails)	*Acanthinucella punctulata*	Muhs and Groves 2018
	Acanthinucella spirata	Lipps et al. 1968, Muhs and Groves 2018
	Acmaea mitra	Lipps et al. 1968, Muhs and Groves 2018
	Acmaea cf. *A. scutum*	Lipps et al. 1968
	Acteocina sp.	Muhs and Groves 2018
	Actonia oldroydae	Muhs and Groves 2018
	Aesopus chrysalloides	Lipps et al. 1968, Muhs and Groves 2018
	Alia carinata	Lipps et al. 1968, Muhs and Groves 2018
	Alvania cosmia	Lipps et al. 1968, Muhs and Groves 2018

Appendix Table A-5-b (continued). Paleontological Quaternary invertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Alvania purpurea*	Lipps et al. 1968, Muhs and Groves 2018
	Alvania cf. *A. aequisculpta*	Lipps et al. 1968
	Amphissa versicolor	Lipps et al. 1968, Muhs and Groves 2018
	Amphithalamus tenuis	Lipps et al. 1968, Muhs and Groves 2018
	Antisabia panamensis	Muhs and Groves 2018
	Assiminea californica	Muhs and Groves 2018
	Assiminea translucens	Lipps et al. 1968
	Balcis aff. *B. delmontensis*	Lipps et al. 1968
	Barbarofusus cf. *B. arnoldi*	Lipps et al. 1968
	Barbarofusus sp.	Muhs and Groves 2018
	Barleeia haliotiphila	Lipps et al. 1968, Muhs and Groves 2018
	Barleeia sp.	Muhs and Groves 2018
	Bittium armillatum catalinense	Lipps et al. 1968
	Bittium interfossa	Lipps et al. 1968
	Caecum californicum	Lipps et al. 1968, Muhs and Groves 2018
	Calicantharus fortis	Lipps et al. 1968, Muhs and Groves 2018
	Californiconus californicus	Lipps et al. 1968, Muhs and Groves 2018
	Callianax biplicata	Lipps et al. 1968, Muhs and Groves 2018
	?*Calliostoma* sp.	Muhs and Groves 2018
	Cerithiopsis antefilosa	Muhs and Groves 2018
	Cerithiopsis cf. *C. antefilosa*	Lipps et al. 1968
	Cerithiopsis sp.	Lipps et al. 1968
	Chlorostoma funebralis	Lipps et al. 1968, Muhs and Groves 2018
	Chlorostoma gallina	Lipps et al. 1968, Muhs and Groves 2018
	Coleophysis? cf. *C. harpa*	Lipps et al. 1968
	Crepidula adunca	Muhs and Groves 2018
	Crepidula nummaria	Lipps et al. 1968
	Crepidula perforans	Muhs and Groves 2018
	Crepidula sp.	Muhs and Groves 2018
	Crepipatella lingulata	Lipps et al. 1968, Muhs and Groves 2018
	Crockerella conradiana	Lipps et al. 1968
	Cystiscus regularis	Lipps et al. 1968
	Diodora arnoldi	Muhs and Groves 2018
	Discurria insessa	Lipps et al. 1968, Muhs and Groves 2018
	Eulithidium sp.	Muhs and Groves 2018
	Fartulum orcutti	Lipps et al. 1968, Muhs and Groves 2018

Appendix Table A-5-b (continued). Paleontological Quaternary invertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Fissurella volcano*	Lipps et al. 1968, Muhs and Groves 2018
	Fusinus luteopictus	Lipps et al. 1968
	Gibberulina pyriformis	Lipps et al. 1968
	Granulina margaritula	Muhs and Groves 2018
	Haliotis cracherodii	Lipps et al. 1968, Muhs and Groves 2018
	Haliotis rufescens	Muhs and Groves 2018
	Haliotis cf. *H. assimilis*	Lipps et al. 1968
	Haliotis sp.	Kemnitzer 1933, Lipps et al. 1968, Muhs and Groves 2018
	Harfordia harfordii	Muhs and Groves 2018
	Harfordia sp.	Muhs and Groves 2018
	Hipponix antiquatus	Lipps et al. 1968
	Hipponix tumens	Lipps et al. 1968, Muhs and Groves 2018
	Homalopoma luridum	Lipps et al. 1968, Muhs and Groves 2018
	Homalopoma paucicostatum	Lipps et al. 1968
	Homalopoma radiatum	Muhs and Groves 2018
	Hyalina californica	Lipps et al. 1968
	Jeffreysia? *californica*	Lipps et al. 1968
	Lacuna carinata	Lipps et al. 1968
	Lacuna unifasciata	Muhs and Groves 2018
	Lirobittium attenuatum	Lipps et al. 1968, Muhs and Groves 2018
	Lirobittium quadrifilatum	Muhs and Groves 2018
	Lirobittium sp.	Muhs and Groves 2018
	Lirularia sp.	Muhs and Groves 2018
	Littorina keenae	Muhs and Groves 2018
	Littorina planaxis	Lipps et al. 1968
	Littorina scutulata	Lipps et al. 1968, Muhs and Groves 2018
	Lottia limatula	Lipps et al. 1968, Muhs and Groves 2018
	Lottia pelta	Lipps et al. 1968, Muhs and Groves 2018
	Lottia scabra	Lipps et al. 1968
	Lottia sp.	Muhs and Groves 2018
	Mangelia aff. *M. interfossa*	Lipps et al. 1968
	Megastraea undosa	Muhs and Groves 2018
	Megatebennus bimaculatus	Lipps et al. 1968
	Melanella thersites	Lipps et al. 1968, Muhs and Groves 2018
	Mexacanthina lugubris	Lipps et al. 1968, Muhs and Groves 2018

Appendix Table A-5-b (continued). Paleontological Quaternary invertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Micrarionta intermedia*	Pilsbry 1939, Roth 1996b
	Mitra idae	Muhs and Groves 2018
	Mitrella tuberosa	Muhs and Groves 2018
	Nassarius mendicus	Lipps et al. 1968, Muhs and Groves 2018
	Neobernaya spadicea	Muhs and Groves 2018
	Norrisia norrisii	Lipps et al. 1968, Muhs and Groves 2018
	Ocenebra cf. *O. foveolata*	Lipps et al. 1968
	Ocenebra cf. *O. interfossa*	Lipps et al. 1968
	Ocinebrina atropurpurea	Muhs and Groves 2018
	Ocinebrina lurida	Muhs and Groves 2018
	Ocinebrina sp.	Muhs and Groves 2018
	Odostomia lucca	Muhs and Groves 2018
	Odostomia nota	Muhs and Groves 2018
	Odostomia oldroydi	Lipps et al. 1968
	Odostomia oregonensis	Muhs and Groves 2018
	Odostomia virginalis	Lipps et al. 1968
	Odostomia cf. *O. sanctorum*	Lipps et al. 1968
	Opalia borealis	Muhs and Groves 2018
	Opalia wroblewskyi chacei	Lipps et al. 1968
	Perimangelia interfossa	Muhs and Groves 2018
	Petaloconchus anellum	Lipps et al. 1968
	Petaloconchus montereyensis	Muhs and Groves 2018
	Petaloconchus cf. *P. complicatus*	Lipps et al. 1968
	Petaloconchus sp.	Muhs and Groves 2018
	Plesiocystiscus politulus	Muhs and Groves 2018
	Pseudodiala acuta	Lipps et al. 1968, Muhs and Groves 2018
	Pseudomelatoma penicillata	Muhs and Groves 2018
	Pseudomelatoma cf. *P. moesta*	Lipps et al. 1968
	Pseudomelatoma sp.?	Lipps et al. 1968, Muhs and Groves 2018
	Pupillaria optabilis	Lipps et al. 1968
	Schwartziella californica	Muhs and Groves 2018
	Schwartziella cf. *S. californica*	Lipps et al. 1968
	Seila montereyensis	Lipps et al. 1968, Muhs and Groves 2018
	Siphonaria brannani	Muhs and Groves 2018
	Tectura paleacea	Muhs and Groves 2018
	Tegula montereyi	Lipps et al. 1968

Appendix Table A-5-b (continued). Paleontological Quaternary invertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Mollusca: Gastropoda (snails) (continued)	*Teinostoma supravallatum*	Lipps et al. 1968, Muhs and Groves 2018
	Teinostoma cf. *T. supravallatum*	Lipps et al. 1968
	Thylacodes squamigerus	Lipps et al. 1968, Muhs and Groves 2018
	Tricolia cf. *T. pulloides*	Lipps et al. 1968
	Trimusculus reticulatus	Lipps et al. 1968, Muhs and Groves 2018
	Triphora pedroana	Muhs and Groves 2018
	Triphora cf. *T. pedroana*	Lipps et al. 1968
	Triphora sp.	Lipps et al. 1968
	Truncatella californica	Muhs and Groves 2018
	Truncatella stimpsonii	Lipps et al. 1968
	Volvarina taeniolata	Muhs and Groves 2018
	Xerarionta tryoni	Lipps et al. 1968
	Xerarionta (*Plesarionta*) *tryoni hemphilli*	Roth and Sadeghian 2006
	Xerarionta sp.	Muhs and Groves 2018
	Epitoniidae indeterminate	Muhs and Groves 2018
	Undetermined land snails	Collins et al. 2018b
Annelida (segmented worms)	Polychaete tube?	Muhs and Groves 2018
Arthropoda: Crustacea: Cirripedia (barnacles)	Cirripedia undetermined	Muhs and Groves 2018
Arthropoda: Crustacea: Decapoda: Brachyura (crabs)	Brachyura undetermined	Collins et al. 2018b, Muhs and Groves 2018
Arthropoda: Crustacea: Ostracoda (seed shrimp)	*Bairdia verdesensis*	Lipps et al. 1968
	Brachycythere lincolnensis	Lipps et al. 1968
	Brachycythere sp.	Lipps et al. 1968
	Bradleya diegoensis	Lipps et al. 1968
	Cytherelloidea sp.	Lipps et al. 1968
	Haplocytheridea cf. *H. maia*	Lipps et al. 1968
	Hemicythere jollaensis	Lipps et al. 1968
	Hemicythere palosensis	Lipps et al. 1968
	Hemicytherura cf. *H. clathrata*	Lipps et al. 1968
	Paracypris pacifica	Lipps et al. 1968
	Sclerochilus? cf. *S. nasus*	Lipps et al. 1968
	Urocythereis glauca	Lipps et al. 1968
	Xestoleberis cf. *X. aurantia*	Lipps et al. 1968
	Xestoleberis sp.	Lipps et al. 1968
	Ostracoda undetermined	Lipps et al. 1968

Appendix Table A-5-b (continued). Paleontological Quaternary invertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Arthropoda: Insecta	Insecta undetermined	Collins et al. 2018b
Echinodermata: Echinoidea (sea urchins)	Echinoidea undetermined	Collins et al. 2018b, Muhs and Groves 2018
Other invertebrates	Shell fragments	Kemnitzer 1933

Appendix Table A-5-c. Paleontological Quaternary vertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Actinopterygii (ray-finned fish)	Actinopterygii undetermined	Collins et al. 2018b, Muhs and Groves 2018
Reptilia: Lacertilia (lizards)	*Xantusia riversiana*	Collins et al. 2018b
Aves	Aves undetermined	Collins et al. 2018b
Aves: Podicipediformes (grebes)	*Podiceps nigricollis*	Collins et al. 2018b
Aves: Procellariiformes (petrels)	*Oceanodroma homochroa*	Collins et al. 2018b
	Oceanodroma leucorhoa	Collins et al. 2018b
Aves: Suliformes (gannets and cormorants)	*Phalacrocorax pelagicus*	Collins et al. 2018b
	Phalacrocorax penicillatus	Collins et al. 2018b
Aves: Pelecaniformes (pelicans, herons, etc.)	*Egretta thula*	Collins et al. 2018b
Aves: Charadriiformes (gulls, waders, etc.)	*Larus heermanni*	Collins et al. 2018b
	Mancalla cf. *californiensis*	LACM collections
	Ptychoramphus aleuticus	Collins et al. 2018b
	Synthliboramphus scrippsi	Collins et al. 2018b
Aves: Gruiformes (crane-like birds)	*Rallus limicola*	Collins et al. 2018b
Aves: Accipitriformes (eagles, hawks, etc.)	*Haliaeetus leucocephalus*	Lipps et al. 1968
Aves: Strigiformes (owls)	*Athene cunicularia*	Collins et al. 2018b
	Tyto alba	Collins et al. 2018b
Aves: Passeriformes (perching birds)	*Artemisiospiza* sp.	Collins et al. 2018b
	Catharus guttatus	Collins et al. 2018b
	cf. *Certhia americana*	Collins et al. 2018b
	Cistothorus palustris	Collins et al. 2018b
	cf. *Contopus sordidulus*	Collins et al. 2018b
	Empidonax difficilis	Collins et al. 2018b
	Eremophila alpestris	Collins et al. 2018b
	cf. *Geothlypis trichas*	Collins et al. 2018b

Appendix Table A-5-c (continued). Paleontological Quaternary vertebrate taxa reported from Santa Barbara Island.

Group	Taxon	References
Aves: Passeriformes (perching birds) (continued)	*Haemorhous mexicanus*	Collins et al. 2018b
	Hirundo rustica	Collins et al. 2018b
	Ixoreus naevius	Collins et al. 2018b
	Junco hyemalis	Collins et al. 2018b
	Melospiza lincolnii	Collins et al. 2018b
	Melospiza melodia	Collins et al. 2018b
	Mimus polyglottos	Collins et al. 2018b
	Oreothlypis celata	Collins et al. 2018b
	Passerculus sandwichensis	Collins et al. 2018b
	Passerella iliaca	Collins et al. 2018b
	Passerina amoena	Collins et al. 2018b
	Pipilo maculatus	Collins et al. 2018b
	Regulus calendula	Collins et al. 2018b
	Salpinctes obsoletus	Collins et al. 2018b
	Setophaga coronata	Collins et al. 2018b
	Setophaga townsendi	Collins et al. 2018b
	Spinus psaltria	Collins et al. 2018b
	cf. *Spinus tristis*	Collins et al. 2018b
	Spizella passerina	Collins et al. 2018b
	Thryomanes bewickii	Collins et al. 2018b
	cf. *Troglodytes pacificus*	Collins et al. 2018b
	Zonotrichia atricapilla	Collins et al. 2018b
	Zonotrichia leucophrys	Collins et al. 2018b
	Passeriformes undetermined	Collins et al. 2018b
Mammalia: Rodentia	*Peromyscus maniculatus*	Collins et al. 2018b
Mammalia: Pinnipedia	*Zalophus* sp.	Lipps et al. 1968

Appendix Table A-5-d. Quaternary ichnofossils and other fossils reported from Santa Barbara Island.

Group	Taxon	References
Vertebrate ichnofossils	Bird eggshells	Collins et al. 2018b
	Owl pellets	Collins et al. 2018b
Foraminifera	*Bolivina pseudoplicata*	Lipps et al. 1968
	Bolivina quadrata	Lipps et al. 1968
	Bolivina vaughani	Lipps et al. 1968
	Bolivina sp.	Lipps et al. 1968

Appendix Table A-5-d (continued). Quaternary ichnofossils and other fossils reported from Santa Barbara Island.

Group	Taxon	References
Foraminifera (continued)	*Cibicides fletcheri*	Lipps et al. 1968
	Cibicides lobatulus	Lipps et al. 1968
	Cribroelphidium poeyanum	Lipps et al. 1968
	Dyocibicides biserialis	Lipps et al. 1968
	Elphidium fax	Lipps et al. 1968
	Eponides repandus	Lipps et al. 1968
	Fissurina marginata	Lipps et al. 1968
	Fissurina marginatoperforata	Lipps et al. 1968
	Glabratella sp.	Lipps et al. 1968
	Globigerina bulloides	Lipps et al. 1968
	Globigerinoides ruber	Lipps et al. 1968
	Islandiella quadrata	Lipps et al. 1968
	Lenticulina sp.	Lipps et al. 1968
	Melonis sp.	Lipps et al. 1968
	Miliolinella circularis	Lipps et al. 1968
	Neoconorbina terquemi	Lipps et al. 1968
	Oolina costata	Lipps et al. 1968
	Oolina melo	Lipps et al. 1968
	Patellina corrugata	Lipps et al. 1968
	Planorbulina mediterranensis	Lipps et al. 1968
	Pyrgo williamsoni	Lipps et al. 1968
	Quinqueloculina akneriana	Lipps et al. 1968
	Quinqueloculina angulostriata	Lipps et al. 1968
	Quinqueloculina costata	Lipps et al. 1968
	Quinqueloculina laevigata	Lipps et al. 1968
	Quinqueloculina microcostata	Lipps et al. 1968
	Rosalina globularis	Lipps et al. 1968, Delaca and Lipps 1972
	Rotorbinella campanulata	Lipps et al. 1968
	Scutuloris redondoensis	Lipps et al. 1968
	Scutuloris cf. *S. redondoensis*	Lipps et al. 1968
	Spirillina lajollaensis	Lipps et al. 1968
	Spiroculina californica	Lipps et al. 1968
	Suggrunda eckisi	Lipps et al. 1968
	Textularia cf. *T. conica*	Lipps et al. 1968
	Trifarina semitrigona	Lipps et al. 1968
	Foraminifera undetermined	Vedder and Howell 1976

Taxonomic Revisions

The names of many taxa reported from CHIS have changed over the years, because of synonymization, splitting, and other reasons. It is beyond the scope of this document to attempt to determine valid names for all taxa, nor to collate modifications to the numerous names outside of the CHIS literature. Instead, the most recent version of a name as it appears in a publication about CHIS is used as the name of record, and older versions are listed below. The most recent name, and therefore the name used in the tables, is the right-most name.

Acanthina lugubris = *Mexacanthina lugubris*
Acanthina spirata = *Acanthinucella spirata*
Acanthina spirata punctulata = *Acanthinucella punctulata*
Acmaea conus = *Lottia conus*
Acmaea insessa = *Discurria insessa*
Acmaea limatula = *Collisella limatula* = *Lottia limatula*
Acmaea pelta = *Lottia pelta*
Acmaea pelta nacelloides = *Lottia pelta*
Acmaea scabra = *Collisella scabra* = *Lottia scabra*
Acmea stimpsoni = *Truncatella stimpsonii*
Alectrion churchi = *Nassarius* (*Catilon*) *churchi*
Aletes squamigerus = *Serpulorbis squamigerus* = *Thylacodes squamigerus*
Astraea undosa = *Megastraea undosa*
Astyris tuberosa = *Mitrella tuberosa*
Balcis thersites = *Melanella thersites*
Bittium attenuatum = *Lirobittium attenuatum*
Bittium eschrichtii = *Stylidium eschrichtii* = *Neostylidium eschrichtii*
Cantharus fortis = *Calicantharus fortis*
Cardita montereyana of Weaver and Meyer (1969) may be *Venericardia montereyana*; combination *Cardita montereyana* not otherwise published
Cardium vaquerosensis = *Trachycardium vaquerosensis*
Cerorhinca monocerata of Lipps (1964) and Howard (1968) = *Fratercula dowi*
Chen caerulescens = *Anser caerulescens*
Clathurella conradiana = *Crockerella conradiana*
Collisella edmitchelli = *Lottia edmitchelli*
Conus californicus = *Californiconus californicus*
Crotalus viridis cf. *helleri* of Guthrie 1993 included in *Crotalus viridis*
Delectopecten peckhami = *Pecten peckhami*
Dendrophyllia variabilis ?= *Balanophyllia variabilis* (essentially unused combination)
Diala acuta = *Pseudodiala acuta*
Diomedea albatrus = *Phoebastria albatrus*
Discoasteroides kuepperi = *Discoaster kuepperi*
Dosidinia = *Dosinia*
Echinarachnius fairbanksi = *Vaquerosella fairbanksi* = *Scutella fairbanksi* = *Kewia fairbanksi*
Egesta pertenuis = *Clementia pertenuis*

Elephas exilis = *Archidiskodon exilis* = *Mammuthus jeffersoni exilis* = *Mammuthus exilis*
Endomychura hypoleuca = *Synthliboramphus hypoleucus*
Ficus (*Trophosycon*) *ocoyanus* = *Trophosycon ocoyana*
Fratercula sp. (Guthrie 1992) = *Fratercula* sp. nov. (Guthrie 1993) = *Cerorhinca* undescribed species (Guthrie 1998) = *Fratercula dowi*
Gerrhonotus multicarinatus = *Elgaria multicarinata*
Glans subquadrata = *Glans carpenteri*
Globotruncana helvetica = *Praeglobotruncana helvetica*
Helminthoglypta ayresiana lesteri = *Helminthoglypta ayresiana*
Hima mendica = *Nassarius mendicus*
Hinnites multirugosus = *Crassadoma gigantea*
Homalopoma carpenteri = *Homalopoma luridum*
Lucina californica = *Epilucina californica*
Lyropecten bowersi = *Vertipecten bowersi*
Mammuthus imperator = *Mammuthus columbi*
Micrarionta facta form *intermedia* = *Micrarionta* (*Micrarionta*) *intermedia*
Micrarionta sodalis of Lipps et al. (1968) = *Micrarionta intermedia* (Pearce 1990)
Micrarionta tryoni = *Xerarionta tryoni*
Microtus sp. nov. = *Microtus miguelensis*
Mitella polymerus = *Pollicipes polymerus*
Mitrella carinata = *Alia carinata*
Nassarius churchi of Bremner (1932) = *Cancellaria* sp.
Nassarius mendicus cooperi = *Nassarius mendicus*
Nonionia sp. of Rand (1931) = *Nonion costiferum*
Ocenebra lurida = *Ocinebrina lurida*
Ocenebra lurida aspera = *Ocinebrina lurida*
Olivella biplicata = *Callianax biplicata*
Ostrea englekyi = *Crassostrea*? *englekyi*
Ostrea haleyi = *Phygraea haleyi*
Ostrea loeli = *Ostrea vespertina loeli*
Ostrea miguelensis = *Acutostrea*? *miguelensis*
Ostrea titan subtitan = *Crassostrea titan subtitan*
Ostrea wiedeyi = *Pycnodonte*? (*Pycnodonte*?) *wiedeyi*
Pallochiton laguminosus = *Pallochiton lanuginosus*
Pecten (*Lyropecten*) *miguelensis* = *Pecten miguelensis* = *Lyropecten miguelensis*
Pecten crassicardo = *Lyropecten crassicardo* (*Pecten crassicardo* of "lower Vaqueros" in Bremner 1933 is *L. pretiosus* per Smith 1991)
Vaquerosian *Pecten crassicardo* of Bremner (1932) = *Lyropecten pretiosus*
Pecten healeyi = *Patinopecten healeyi*
Pecten miguelensis submiguelensis = *Lyropecten pretiosus*
Pecten miguelensis supervariant = *Lyropecten miguelensis*
Pecten submiguelensis = *Lyropecten pretiosus*

Pecten vanvlecki = *Amussiopecten vanvlecki*
Unnamed *Peromyscus* sp. of Lipps (1964) = *Peromyscus anyapahensis*
Peromyscus sp. mentioned in Orr (1962) at the Arlington Site = *P. nesodytes* (Agenbroad et al. 2005)
Phacoides sp. of Rand (1933) = *Lucina* sp.
Pinus remorata is sometimes sunk into *P. muricata*, or given as *P. m.* var. *remorata*
Pododesmus macroschisma = *Pododesmus macrochisma*
Pseudotsuga taxifolia = *Pseudotsuga menziesii*
Rapana vaquerosensis imperialis = *Rapana imperialis*
Rissoina californica = *Schwartziella californica*
Scutella fairbanksi = *Kewia fairbanksi*
Scutella norrisi = *Echinarachnius norrisi*
Scutella vaquerosensis = *Echinarachnius vaquerosensis*
Siphogenerina cf. *S. collomi* of Rand (1931) = *Siphogenerina nuciformis*
Spiroglyphus is an obsolete name that may pertain to polychaete worm tubes instead of worm-like snails (Bieler and Petit 2011); Shapiro (1998) included it in a list of gastropods without comment
Tegula brunnea = *Chlorostoma brunnea*
Tegula funebralis = *Chlorostoma funebralis*
Tegula gallina multifilosa = *Chlorostoma gallina*
Tegula spp. = *Chlorostoma* spp.
Transennella tantilla = *Nutricola tantilla*
Tritonalia lurida = *Ocinebrina lurida*
Turritella pachecoensis = *Turritella infragranulata pachecoensis*
Turritella tritschi = *Turritella temblorensis tritschi*
Zonaria spadicea = *Neobernaya spadicea*

Appendix B: Taxa Named from CHIS Fossils

Twenty-three fossil taxa have been named from specimens collected on the islands of CHIS: 17 invertebrates, five vertebrates, and a foraminiferan. They are listed below in alphabetical order of genus and then species (Appendix Table B). The table includes the original taxonomic designation, citation, provenance (age, formation, and island), type specimen, and notes, which include the broad taxonomic category and updates to the taxonomy. In some cases, the author did not distinguish between the Rincon and Vaqueros formations; such cases are reported as "Vaqueros / Rincon." The updates are not exhaustive, due to the subjective nature of taxonomy and the difficulty of uncovering every possible taxonomic opinion. Citations are included under "Literature Cited."

Island abbreviations:

- AI = Anacapa Island
- SBI = Santa Barbara Island
- SCI = Santa Cruz Island
- SMI = San Miguel Island
- SRI = Santa Rosa Island

Institutional abbreviations:

- ANSP = Academy of Natural Sciences of Drexel University (formerly the Academy of Natural Sciences of Philadelphia), Philadelphia, Pennsylvania
- CAS = California Academy of Sciences, San Francisco, California
- CIT = California Institute of Technology, Pasadena, California (collections now at the Natural History Museum of Los Angeles County)
- CWRUHO = Case Western Reserve University, Cleveland (section of collection now at the University of California Museum of Paleontology)
- LACM = Natural History Museum of Los Angeles County, Los Angeles, California (formerly the Los Angeles County Museum of Natural History)
- LACMIP = Invertebrate paleontology collection of the Natural History Museum of Los Angeles County, Los Angeles, California
- SBMNH = Santa Barbara Museum of Natural History, Santa Barbara, California
- UCLA = University of California, Los Angeles, Los Angeles, California (collections now at the Natural History Museum of Los Angeles County)
- UCMP = University of California Museum of Paleontology, Berkeley, California

Appendix Table B. Fossil taxa named from specimens found within CHIS.

Taxon	Citation	Provenance	Type Specimen	Notes
Alectrion churchi	Hertlein 1928	Miocene, Vaqueros, SRI	CAS 4149	Gastropod, now *Nassarius churchi*
Asio priscus	Howard 1964b	Pleistocene, SRI	LACM 4712	Owl
Brissus kewi	Grant and Hertlein 1938	Miocene, Vaqueros, SRI	UCLA 6326 (now LACMIP 9133)	Echinoid
Calliostoma augustinensis	Hertlein 1928	Miocene, Vaqueros, SRI	CAS 4146	Gastropod
Elephas exilis	Stock and Furlong 1928	Pleistocene, SRI	CIT 14 (now at LACM)	Proboscidean, now *Mammuthus exilis*
Fissurella rixfordi	Hertlein 1928	Miocene, Vaqueros / Rincon, SMI	CAS 4145	Gastropod
Globotruncana marianosi	Douglas 1969	Cretaceous, Jalama, SMI	CWRUHO13 (now UCMP 49003, slide 3110)	Foraminifera
Helminthoglypta ayresiana lesteri	Cockerell 1938a	Pleistocene, SMI	ANSP 170430	Gastropod, subspecies generally not used
Lytechinus coreyi	Grant and Hertlein 1938	Miocene, Vaqueros, SRI	UCLA 6805 (now LACMIP 9120)	Echinoid
Micrarionta facta form *intermedia*	Pilsbry 1939 ex. Hemphill ms.	Pleistocene, SBI	ANSP 86840a	Gastropod, now *Micrarionta intermedia*
Microtus miguelensis	Guthrie 1998	Pleistocene, SMI	SBMNH 191	Vole
Ostrea englekyi	Hertlein 1928	Miocene, Rincon, SRI	CAS 4116	Bivalve, now *Crassostrea*? *englekyi*
Ostrea haleyi	Hertlein 1933	Paleocene, Pozo, SCI	CAS 5526	Bivalve, now *Phygraea haleyi*
Ostrea loeli	Hertlein 1928	Miocene, Vaqueros, SRI	CAS 4117	Bivalve, now *O. vespertina loeli*
Ostrea miguelensis	Hertlein 1928	Miocene, Vaqueros / Rincon, SMI	CAS 4121	Bivalve, now *Acutostrea*? *miguelensis*
Ostrea wiedeyi	Hertlein 1928	Miocene, Vaqueros, SRI	CAS 4129	Bivalve, now *Pycnodonte*? *wiedeyi*
Pecten (*Lyropecten*) *miguelensis*	Arnold 1906	Miocene, Vaqueros / Rincon, SMI	UCMP 12079	Bivalve, now *Lyropecten miguelensis*
Pecten miguelensis var. *submiguelensis*	Loel and Corey 1932	Miocene, Vaqueros, SRI	UCMP 31737	Bivalve, now assigned to *Lyropecten pretiosus*
Peromyscus anyapahensis	White 1966	Pleistocene, AI	LACM 9205	Mouse
Peromyscus nesodytes	Wilson 1936	Pleistocene, SRI	CIT 1780 (now LACM CIT 1780)	Mouse
Placunanomia granti	Hertlein 1928	Miocene, Vaqueros, SRI	CAS 4140	Bivalve
Pteria rositae	Hertlein 1928	Miocene, Rincon, SRI	CAS 4142	Bivalve
Turritella tritschi	Hertlein 1928	Miocene, Vaqueros, SRI	CAS 4150	Gastropod, now *T. temblorensis tritschi*

Appendix C: Outside Repositories of CHIS Fossils

The institutions known to have collections from the islands of CHIS are included below. Addresses, phone numbers, links, and email addresses to departments are included as available. Hyperlinks are subject to change without warning.

ACADEMY OF NATURAL SCIENCES OF DREXEL UNIVERSITY
1900 Benjamin Franklin Parkway
Philadelphia, PA 19103
(215) 299-1000
https://ansp.org/
https://ansp.org/research/systematics-evolution/malacology/

The Academy of Natural Sciences of Drexel University reposits a small number of relevant fossils, including the type material of Pleistocene gastropods *Helminthoglypta ayresiana lesteri* and *Micrarionta facta* form *intermedia*.

CALIFORNIA ACADEMY OF SCIENCES
55 Music Concourse Drive
San Francisco, CA 94118
(415) 379-8000
https://www.calacademy.org/
https://www.calacademy.org/scientists/department-of-invertebrate-zoology-and-geology-history

The California Academy of Sciences reposits numerous fossils from the islands of CHIS. Among them are 11 holotypes, specimens transferred from the California State Mining Bureau that were collected during C. D. Voy's work on San Miguel and Santa Rosa islands in the 1890s, and specimens formerly held by Stanford and Union Oil Company.

CINCINNATI MUSEUM CENTER
1301 Western Avenue
Cincinnati, OH 45203
(513) 287-7000
https://www.cincymuseum.org/
information@cincymuseum.org

The Cincinnati Museum Center holds five Miocene mollusks from Santa Rosa and Santa Cruz.

MAMMOTH SITE OF HOT SPRINGS
1800 US 18 Bypass
PO Box 692
Hot Springs, SD 57747
(605) 745-6017
https://www.mammothsite.org/
news@mammothsite.org

The Mammoth Site of Hot Springs currently has the Larramendy mammoth skull for preparation, and also has microvertebrate material on loan from CHIS.

NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY
900 Exposition Blvd
Los Angeles, CA 90007
(213) 763-3466
https://nhm.org/
https://nhm.org/research-collections/departments/invertebrate-paleontology (Invertebrate Paleontology)
invpaleo@nhm.org (Invertebrate Paleontology general contact)
https://nhm.org/research-collections/departments/vertebrate-paleontology (Vertebrate Paleontology)
vertpaleo@nhm.org (Vertebrate Paleontology general contact)

The Natural History Museum of Los Angeles County reposits numerous vertebrate and invertebrate fossils from all five islands of CHIS, among them six holotypes (including those of *Mammuthus exilis* and *Peromyscus nesodytes*). The Channel Islands fossils include material originally held at Caltech and UCLA.

LABORATORY OF PALEOECOLOGY
NORTHERN ARIZONA UNIVERSITY, SCHOOL OF EARTH AND SUSTAINABILITY
Room A108 Building 11
Ashurst
624 S Knoles Dr
Flagstaff, AZ 86011
(928) 523 4561
https://nau.edu/ses/
http://www2.nau.edu/ScottAnderson

Dr. Anderson’s lab has charcoal and fossil pollen samples from CHIS.

PEABODY MUSEUM OF NATURAL HISTORY AT YALE UNIVERSITY
P.O. Box 208118
170 Whitney Ave
New Haven, CT 06520
(203) 432-5050
http://peabody.yale.edu/
peabody.collections@yale.edu

The Peabody Museum holds eight lots of foraminifera from Richland Oil Company wells drilled on or near Santa Cruz Island, and an enigmatic collection of bryozoans from Santa Barbara Island.

SANTA BARBARA MUSEUM OF NATURAL HISTORY
2559 Puesta del Sol
Santa Barbara, CA 93105
(805) 682-4711
https://www.sbnature.org/
info@sbnature2.org

The Santa Barbara Museum of Natural History reposits CHIS's paleontological collections.

SAN DIEGO NATURAL HISTORY MUSEUM
1788 El Prado, Balboa Park
San Diego, CA 92101
Mailing address PO Box 121390, San Diego, CA 92112-1390
(619) 232-3821
https://www.sdnhm.org/
https://www.sdnhm.org/science/paleontology/

The San Diego Natural History Museum holds substantial collections of Pleistocene fossils from Anacapa and Santa Cruz islands.

UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY
Museum of Paleontology
University of California
1101 Valley Life Sciences Building
Berkeley, CA 94720-4780
(510) 642-1822
https://ucmp.berkeley.edu/
https://ucmp.berkeley.edu/contact-ucmp/

The University of California Museum of Paleontology holds fossils from at least four of the five CHIS islands, including three holotypes and the former collections of USGS-Menlo Park.

UNIVERSITY OF CALIFORNIA, SANTA BARBARA
Department of Earth Sciences
College of Letters & Science
University of California
Santa Barbara, CA 93106
(805) 893-4688
https://www.geol.ucsb.edu/
https://www.ccber.ucsb.edu/collections/paleontology

The University of California, Santa Barbara reposits hundreds of fossils from the islands of CHIS, notable a large number of specimens from Santa Cruz Island.

WESTERN ARCHEOLOGICAL AND CONSERVATION CENTER
255 N Commerce Park Loop
Tucson, AZ 85745
520-791-6400
https://www.nps.gov/orgs/1260/index.htm

The Western Archeological and Conservation Center holds two CHIS specimens found in archeological contexts.

Appendix D: Paleontological Resource Law and Policy

The following material is reproduced in large part from Henkel et al. (2015):

In March 2009, the Paleontological Resources Preservation Act (PRPA) (16 USC 460aaa) was signed into law (Public Law 111–11). This act defines paleontological resources as

> *…any fossilized remains, traces, or imprints of organisms, preserved in or on the earth's crust, that are of paleontological interest and that provide information about the history of life on earth.*

The law stipulates that the Secretary of the Interior should manage and protect paleontological resources using scientific principles. The Secretary should also develop plans for

> *…inventory, monitoring, and the scientific and educational use of paleontological resources.*

Paleontological resources are considered park resources and values that are subject to the "no impairment" standard in the National Park Service Organic Act (1916). In addition to the Organic Act, PRPA will serve as a primary authority for the management, protection and interpretation of paleontological resources. The proper management and preservation of these non-renewable resources should be considered by park resource managers whether or not fossil resources are specifically identified in the park's enabling legislation.

The Paleontological Resources Management section of NPS Reference Manual 77 (NPS 2004) provides guidance on the implementation and continuation of paleontological resource management programs. Administrative options include those listed below and a park management program will probably incorporate multiple options depending on specific circumstances:

- **No action**—no action would be taken to collect the fossils as they erode from the strata. The fossils would be left to erode naturally and over time crumble away, or possibly be vandalized by visitors, either intentionally or unintentionally.
- **Surveys**—will be set up to document potential fossil localities. All sites will be documented with the use of GPS and will be entered into the park GIS database. Associated stratigraphic and depositional environment information will be collected for each locality. A preliminary faunal list will be developed. Any evidence of poaching activity will be recorded. Rates of erosion will be estimated for the site and a monitoring schedule will be developed based upon this information. An NPS Paleontological Locality Database Form will also be completed for each locality. A standard version of this form will be provided by the Paleontology Program of the Geologic Resources Division upon request and can be modified to account for local conditions and needs.
- **Monitoring**—fossil-rich areas would be examined periodically to determine if conditions have changed to such an extent that additional management actions are warranted. Photographic records should be kept so that changes can be more easily ascertained.

- **Cyclic prospecting**—areas of high erosion which also have a high potential for producing significant specimens would be examined periodically for new sites. The periodicity of such cyclic prospecting will depend on locality-specific characteristics such as rates of sediment erosion, abundance or rarity of fossils, and proximity to visitor use areas.
- **Stabilization and reburial**—significant specimens which cannot be immediately collected may be stabilized using appropriate consolidants and reburied. Reburial slows down but does not stop the destruction of a fossil by erosion. Therefore, this method would be used only as an interim and temporary stop-gap measure. In some situations, stabilization of a locality may require the consideration of vegetation. For example, roots can destroy in situ fossils, but can also protect against slope erosion, while plant growth can effectively obscure localities, which can be positive or negative depending on how park staff want to manage a locality.
- **Shelter construction**—it may be appropriate to exhibit certain fossil sites or specimens in situ, which would require the construction of protective shelters to protect them from the natural forces of erosion. The use of shelters draws attention to the fossils and increases the risk of vandalism or theft, but also provides opportunities for interpretation and education.
- **Excavation**—partial or complete removal of any or all fossils present on the surface and potentially the removal of specimens still beneath the surface which have not been exposed by erosion.
- **Closure**—the area containing fossils may be temporarily or permanently closed to the public to protect the fossil resources. Fossil-rich areas may be closed to the public unless accompanied by an interpretive ranger on a guided hike.
- **Patrols**—may be increased in areas of known fossil resources. Patrols can prevent and/or reduce theft and vandalism. The scientific community and the public expect the NPS to protect its paleontological resources from vandalism and theft. In some situations a volunteer site stewardship program may be appropriate (for example the "Paleo Protectors" at Chesapeake & Ohio Canal National Historical Park).
- **Alarm systems/electronic surveillance**—seismic monitoring systems can be installed to alert rangers of disturbances to sensitive paleontological sites. Once the alarm is engaged, a ranger can be dispatched to investigate. Motion-activated cameras may also be mounted to visually document human activity in areas of vulnerable paleontological sites.

National Park Service Management Policies (2006; Section 4.8.2.1) also require that paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. In 2010, the National Park Service established National Fossil Day as a celebration and partnership organized to promote public awareness and stewardship of fossils, as well as to foster a greater appreciation of their scientific and educational value (https://www.nps.gov/subjects/fossilday/index.htm). National Fossil Day occurs annually on Wednesday of the second full week in each October in conjunction with Earth Science Week.

Related Laws, Legislation, and Management Guidelines

National Park Service Organic Act

The NPS Organic Act directs the NPS to manage units

> *…to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner as will leave them unimpaired for the enjoyment of future generations.* (16 U.S.C. § 1).

Congress reiterated this mandate in the Redwood National Park Expansion Act of 1978 by stating that the NPS must conduct its actions in a manner that will ensure no

> *…derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress.* (16 U.S.C. § 1 a-1).

The Organic Act prohibits actions that permanently impair park resources unless a law directly and specifically allows for the acts. An action constitutes an impairment when its impacts

> *…harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources and values.* (Management Policies 2006 1.4.3).

Paleontological Resources Protection Act (P.L. 111-011, Omnibus Public Land Management Act of 2009, Subtitle D)

Section 6302 states:

> *The Secretary (of the Interior) shall manage and protect paleontological resources on Federal land using scientific principles and expertise. The Secretary shall develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources, in accordance with applicable agency laws, regulations, and policies. These plans shall emphasize interagency coordination and collaborative efforts where possible with non-Federal partners, the scientific community, and the general public.*

Federal Cave Resources Protection Act of 1988 (16 USC 4301)

This law provides a legal authority for the protection of all cave resources on NPS and other federal lands. The definition for "Cave Resource" in Section 4302 states:

> *Cave resources include any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems.*

NPS Management Policies 2006

NPS Management Policies 2006 include direction for preserving and protecting cultural resources, natural resources, processes, systems, and values (NPS 2006). It is the goal of the NPS to avoid or minimize potential impacts to resources to the greatest extent practicable consistent with the management policies. The following is taken from section 4.8.2.1 of the NPS Management Policies 2006, "Paleontological Resources and Their Contexts":

> *Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).*
>
> *Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion. Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.*
>
> *The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.*
>
> *Parks will exchange fossil specimens only with other museums and public institutions that are dedicated to the preservation and interpretation of natural heritage and qualified to manage museum collections. Fossils to be deaccessioned in an exchange must fall outside the park's scope of collection statement. Systematically collected fossils in an NPS museum collection in compliance with 36 CFR 2.5 cannot be outside the scope of collection statement. Exchanges must follow deaccession procedures in the Museum Handbook, Part II, chapter 6.*
>
> *The sale of original paleontological specimens is prohibited in parks.*
>
> *The Service generally will avoid purchasing fossil specimens. Casts or replicas should be acquired instead. A park may purchase fossil specimens for the park museum collection only after making a written determination that*

- *The specimens are scientifically significant and accompanied by detailed locality data and pertinent contextual data;*
- *The specimens were legally removed from their site of origin, and all transfers of ownership have been legal;*
- *The preparation of the specimens meets professional standards;*

- *The alternatives for making these specimens available to science and the public are unlikely;*
- *Acquisition is consistent with the park's enabling legislation and scope of collection statement, and acquisition will ensure the specimens' availability in perpetuity for public education and scientific research.*

  All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins. Areas with potential paleontological resources must also be monitored during construction projects.

(See Natural Resource Information 4.1.2; Studies and Collections 4.2; Independent Research 5.1.2; Artifacts and Specimens 10.2.4.6. Also see 36 CFR 2.5.)

NPS Director's Order-77, Paleontological Resources Management
DO-77 describes fossils as non-renewable resources and identifies the two major types: body fossils and trace fossils. It describes the need for managers to identify potential paleontological resources using literature and collection surveys, identify areas with potential for significant paleontological resources, and conduct paleontological surveys (inventory). It also describes appropriate actions for managing paleontological resources including: no action, monitoring, cyclic prospecting, stabilization and reburial, construction of protective structures, excavation, area closures, patrols, and the need to maintain confidentiality of sensitive location information.

Excerpt from Clites and Santucci (2012):

Monitoring

An important aspect of paleontological resource management is establishing a long-term paleontological resource monitoring program. National Park Service paleontological resource monitoring strategies were developed by Santucci et al. (2009). The park's monitoring program should incorporate the measurement and evaluation of the factors stated below.

Climatological Data Assessments

These assessments include measurements of factors such as annual and storm precipitation, freeze/thaw index (number of 24-hour periods per year where temperature fluctuates above and below 32 degrees Fahrenheit), relative humidity, and peak hourly wind speeds.

Rates of Erosion Studies

These studies require evaluation of lithology, slope degree, percent vegetation cover, and rates of denudation around established benchmarks. If a park does not have this information, there may be opportunities to set up joint projects, because erosion affects more than just paleontological resources.

Assessment of Human Activities, Behaviors, and Other Variables

These assessments involve determining access/proximity of paleontological resources to visitor use areas, annual visitor use, documented cases of theft/vandalism, commercial market value of the fossils, and amount of published material on the fossils.

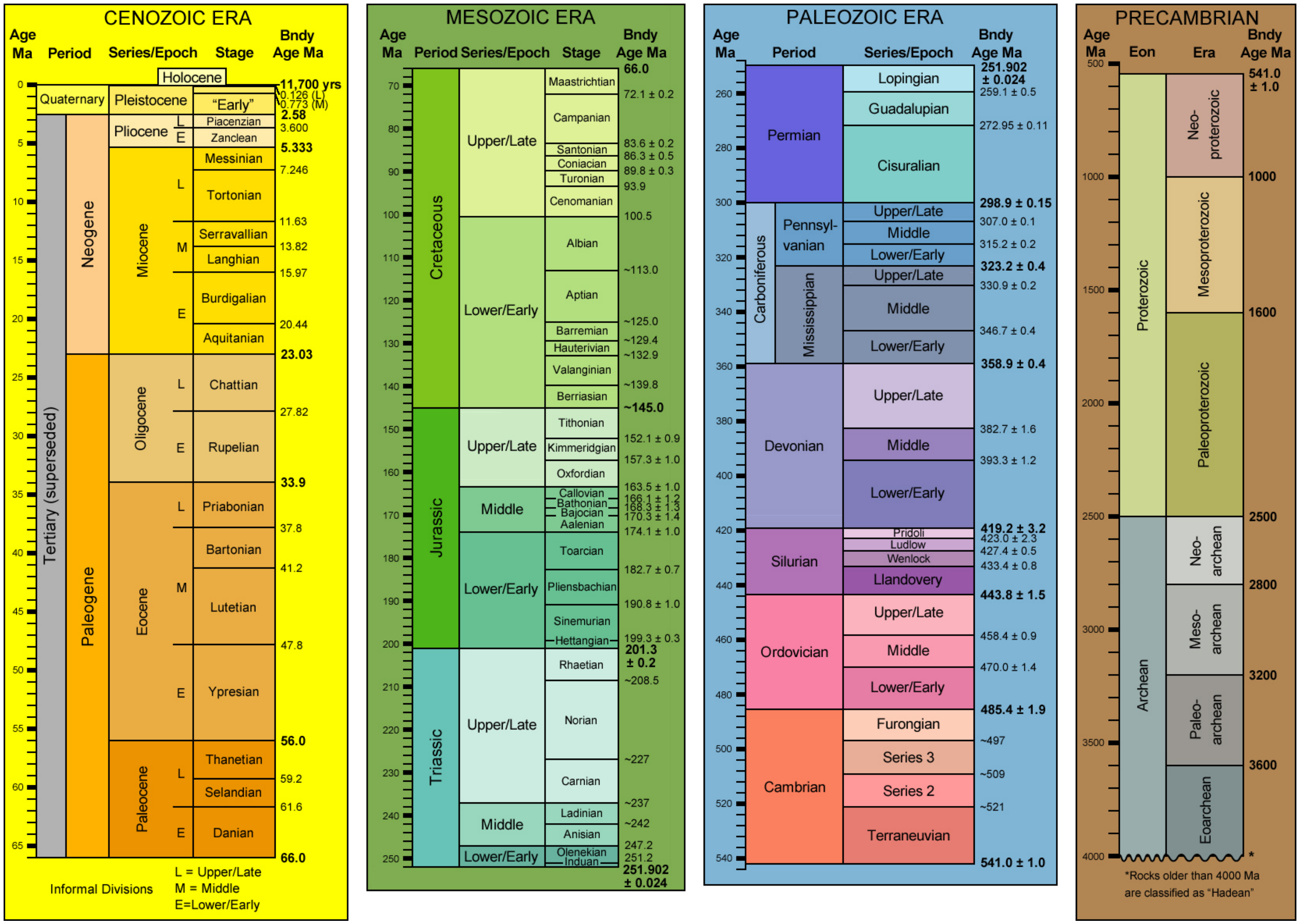
Condition Assessment and Cyclic Prospecting

These monitoring methods entail visits to the locality to observe physical changes in the rocks and fossils, including the number of specimens lost and gained at the surface exposure. Paleontological prospecting would be especially beneficial during construction projects or road repair.

Periodic Photographic Monitoring

Maintaining photographic archives and continuing to photo-document fossil localities from established photo-points enables visual comparison of long-term changes in site variables.

Appendix E: Geologic Time Scale



Ma=Millions of years old. **Bndy Age**=Boundary Age. Modified from 1999 Geological Society of America Time Scale (https://www.geosociety.org/documents/gsa/timescale/timescl-1999.pdf). Dates and additional information from International Commission on Stratigraphy update 2019/05 (https://stratigraphy.org/chart) and USGS Fact Sheet 2007-3015 (https://pubs.usgs.gov/fs/2007/3015/).

The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 159/173718, September 2020

National Park Service
U.S. Department of the Interior

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Fort Collins, CO 80525