Geology of Santa Rosa Island

FIELD TRIP GUIDE

COAST GEOLOGIC SOCIETY
Fall Field Trip
November 20-22, 1998
Geology of Santa Rosa Island

FIELD TRIP GUIDE

By John Woolley

COAST GEOLOGIC SOCIETY
Fall Field Trip

November 20-22, 1998
INTRODUCTION

Santa Rosa Island is one of the four Northern Channel Islands of California, which include (from west to east) San Miguel, Santa Rosa, Santa Cruz and Anacapa Islands. Santa Rosa lies about 50 km SSW of Santa Barbara and about 80 km WSW of Ventura and comprises about 55,000 ac or 200 km$^2$ of rolling, grass-covered hills which reach a maximum elevation of 484 m.

This field trip to Santa Rosa Island is the Coast Geologic Society's Fall Field Trip for 1998. Now is a fortuitous time for this trip as two projects concerning island geology were completed in conjunction with the 1998 AAPG-SEPM-SEG-SPWLA Pacific Section Convention, held in Ventura, California. Growing out of a brief geological study of Santa Rosa for the National Park Service is a new Dibblee map of the island (Dibblee et al., 1998). Also, in conjunction with the Pacific Section meeting a symposium was held on the Western Transverse Ranges, emphasizing the northern Channel Islands. These papers are compiled into a new volume, *Contributions to the Geology of the Northern Channel Islands*, edited by Peter Weigand (AAPG Spec. Pub. 45, 1998).

This brief guide is intended to supplement existing literature, especially papers in the Weigand volume, particularly Dibblee and Ehrenspeck (1998).

The Western Transverse Ranges hold many clues to the transition of southern California from a convergent to a transform margin. The islands have been less thoroughly studied than the mainland simply due to poor accessibility. This trip is a great opportunity to get a glimpse of what Santa Rosa Island can tell us about the geologic history of southern California.

ACKNOWLEDGMENTS

I thank Tom Dibblee and Helmut Ehrenspeck for the maps and figures, and Susan Morris for the cover drawing of the pygmy mammoth discovered on Santa Rosa in 1994. I also thank Peter Weigand and Helmut Ehrenspeck for editorial advice; any errors are mine. I appreciate the help of a number of geologists on the island over the years, including Bob Nuccio and Greg Millikan.

GENERAL GEOLOGY

The Northern Channel Islands are a structural extension of the Santa Monica Mountains, and together they make up the southernmost range of the western Transverse Ranges. About 6300 m of upper Cretaceous through middle Miocene strata are exposed on the islands, including over 2000 m of volcanic rocks. The islands first emerged from the sea perhaps 2 to 3 million years ago due to uplift resulting from regional north-south compression of the Transverse Ranges.

Structurally Santa Rosa is dominated by the east-west trending Santa Rosa Island fault, with 7-12 km of left-slip. It appears to have been active several times in the Holocene and is capable of generating seismic events with ± 5-m of slip at ca. 7500 year intervals (Colson et al., 1995). Other secondary faults are indicated on the map by Dibblee et al. (1998).
Bedrock units generally dip at low angles to the northeast, so the rocks generally get older to the southwest across the island. Several low-amplitude folds are mapped by Dibblee et al. (1998), including the east-plunging Black Mountain anticline north of the Santa Rosa Island fault, and the generally northwest-southeast trending Soledad anticline and Pedregosa syncline to the south of the fault.

Several of these structures were tested by the 12 exploratory oil wells drilled on the island between 1932-1975. Oil and gas shows were noted in only a few of the wells and no production was established.

The geologic units discussed below are listed on the enclosed stratigraphic column (Dibblee and Ehrenspeck, 1998).

**SOUTH POINT FORMATION**

The oldest bedrock unit exposed on Santa Rosa Island is the middle to late Eocene (Ulatisan-Narizian) South Point Formation (Weaver and Doerner, 1969; Abbott et al., 1983; Dibblee and Ehrenspeck, 1998). This sequence of rhythmically bedded sandstone and thin interbedded siltstone was deposited by turbidity currents in a middle fan environment. The sandstone is generally fine to medium grained and occurs in laterally continuous beds from 0.5 to 2 m thick. The siltstone interbeds range from 2 to 15 cm in thickness and often display convolute bedding.

In outcrop the South Point sandstone appears brownish-yellow and often contains spherical concretions up to 1 m in diameter. On upland slopes the unit typically weathers a characteristic orange-red. Weaver and Doerner (1969) measured an exposed section of South Point 213 m thick in Wreck Canyon, near the central part of the south coast. The entire sand-silt section has been penetrated in two exploratory oil wells on the island; thickness ranged from 979 to 1097 m.

Of special note is the apparent correlation between this unit on Santa Rosa and the conglomeratic sandstone of the Jolla Vieja Formation on neighboring Santa Cruz Island. These two units are similar in age and lithology. The major difference is that on Santa Cruz, the section contains conglomerate ranging from 49 to 268 m thick, while no conglomerate is exposed on Santa Rosa. However, in Mobil "Santa Rosa" #5, drilled on the south side of SRI, 375 m of similar conglomerate was penetrated at a depth of 1058 m. Several authors have noted striking similarities between these conglomerates and the rhyolitic "Poway" conglomerates of the same age from San Diego County. These similarities have been cited as evidence for northward translation and/or rotation of the western Transverse Ranges.

**COZY DELL SHALE**

Conformably overlying the South Point is the Cozy Dell Formation consisting of highly fractured gray-brown foraminiferal mudstone and siltstone of late Eocene age (Weaver and Doerner, 1969; Dibblee and Ehrenspeck, 1998). It outcrops in a thin band across the south coast of the island. Maximum exposed thickness measured by Weaver is 125 m; it is 170 to 215 m thick in wells on the northwest part of the island, north of the Santa Rosa Island fault.

West of South Point (the southernmost tip of Santa Rosa Island) the Cozy Dell is
<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
<th>LITHOLOGY &amp; MAP SYMBOL</th>
<th>THICKNESS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUAT</td>
<td>SURFICIAL SEDIMENTS</td>
<td></td>
<td>0 - 60 m (0 - 200 ft)</td>
<td>Alluvium, coastal terrace sediments, dune &amp; drift sand</td>
</tr>
<tr>
<td></td>
<td>UPPER BEECHERS BAY</td>
<td></td>
<td>300 - 600 m (1000 - 2000 ft)</td>
<td>Gray-white, medium- to coarse-grained tuffaceous sandstone, bedded dacite tuff, and volcanic conglomerate of basalt to dacite clasts; includes landslide mass of greenschist-phylite (sc), and thin unit of biogenic shale (Tbs)</td>
</tr>
<tr>
<td></td>
<td>LOWER BEECHERS BAY</td>
<td></td>
<td>500 ± m (1500 ± ft)</td>
<td>Gray conglomerate of volcanics (basalt - dacite), blueschist, mafic gneiss, diorite, quartz &amp; sandstone</td>
</tr>
<tr>
<td></td>
<td>MONTEREY</td>
<td></td>
<td>150 - 500 m (500 - 1500 ft)</td>
<td>Light gray to white, thin-beded, fine-grained sandstone, siltstone and thin beds of rhyolitic (?) tuff</td>
</tr>
<tr>
<td></td>
<td>RINCON</td>
<td></td>
<td>270 - 500 m (600 - 1600 ft)</td>
<td>White-weathering, silceous to semi-siliceous biogenic shale</td>
</tr>
<tr>
<td></td>
<td>VAQUEROS</td>
<td></td>
<td>150 - 210 m (500 - 700 ft)</td>
<td>Basaltic volcaniclastic deposits, rare pillow-breccias and flows, &amp; associated dikes and silts (Tvi)</td>
</tr>
<tr>
<td></td>
<td>SESPE</td>
<td></td>
<td>150 m (500 ft)</td>
<td>Gray crumby claystone and siltstone, some thin interbeds of fine-grained sandstone, in places fossiliferous</td>
</tr>
<tr>
<td>Oligocene (?)</td>
<td>COZY DELL</td>
<td>Tm</td>
<td>200 ± m (600 ± ft)</td>
<td>Light gray to tan, fossiliferous arkosic sandstone</td>
</tr>
<tr>
<td></td>
<td>SOUTH POINT</td>
<td>Tm</td>
<td>1100 ± m (3500 ± ft)</td>
<td>Gray crumby claystone and siltstone, with minor thin partings or interbeds of clay shale</td>
</tr>
<tr>
<td>Eocene</td>
<td>CONGLOMERATE</td>
<td>Te</td>
<td>300 m (1000 ft)</td>
<td>Gray conglomerate of smooth rounded cobbles &amp; pebbles of mostly andesitic metavolcanics (Powyake clasts) in hard sandstone</td>
</tr>
<tr>
<td></td>
<td>UNNAMED UNITS</td>
<td>KT</td>
<td>1900 m (6000 ft)</td>
<td>Hard, dark gray micaceous clay shale with thin sandstone interbeds</td>
</tr>
<tr>
<td></td>
<td>PALEOCENE &amp; LATE CRETACEOUS (?)</td>
<td></td>
<td>50 m (170 ft)</td>
<td>Hard gray sandstone with minor thin micaceous shale interbeds</td>
</tr>
</tbody>
</table>

Figure 2. Stratigraphic column of Santa Rosa Island, using same symbols as in Figures 4 and 5.
absent, suggesting southwestward truncation under a low-angle unconformity. The Cozy Dell is relatively soft and therefore outcrops poorly, forming rounded grassy hills. This mudstone was deposited under bathyal conditions and is considered to be the basin plain equivalent of the South Point turbidites.

**SESPE FORMATION**

Unconformably overlying the Cozy Dell is the Sespe Formation, a terrestrial sequence of fine-to coarse-grained arkosic sandstone, mudstone, and conglomerate (Weaver and Doerner, 1969; Woolley, 1978; 1998a; Dibblee and Ehrenspeck, 1998). In outcrop, it is generally brown and reddish, with local exposures of green and purple. The outcrop is somewhat discontinuous, being broken by faulting, and individual beds are not laterally continuous.

The Sespe fines and thins toward the east. The westernmost exposures, in Bee Canyon on the west coast, contain conglomerate rich in volcanic clasts of intermediate to felsic composition (about 64%), basalt (13%) and well-rounded rhyolite resembling Poway clasts (about 10%). Toward the east near San Augustine Canyon, the unit loses its red conglomeratic character and transitions into the shallow marine sandstone of the Vaqueros Formation. It also interfingers above with the Vaqueros.

Deposition was by braided streams on an alluvial plain very near the coast, such as the Oxnard Plain or Los Angeles Basin today.

No fossils have been found in the Sespe on Santa Rosa Island, but the age is interpreted as latest Oligocene to earliest Miocene based on the age of the overlying Vaqueros as well as that of mainland Sespe. Source for these sediments was a granitic terrane, presumably the Southern California Batholith. Volcanic clasts found in the sandstone and conglomerate were derived from volcanic rocks associated with the batholith. A local uplift of Eocene sedimentary rocks supplied some of the sediment. Paleocurrent directions are generally from the south, supporting the idea of clockwise rotation of the western Transverse Ranges.

**VAQUEROS FORMATION**

Above the Sespe and interfinger ing with it is the Vaqueros Formation, a sequence of shallow marine sandstone, siltstone and conglomerate which marks the flooding of the Sespe alluvial plain by the sea (Avila and Weaver, 1969; Woolley, 1978; 1998a; Dibblee and Ehrenspeck, 1998). Lithologically, the Vaqueros is primarily fine to medium grained fossiliferous arkosic sandstone. Occasional pebble conglomerate has a composition similar to that of the Sespe conglomerate. Sedimentary structures including bioturbation and cross-bedding indicate deposition in shallow marine environments ranging from beach to shallow shelf.

In outcrop, the Vaqueros appears yellow-brown, locally with a greenish tinge. Locally, the sandstone weathers into shallow caverns or has a fracture network infilled with white caliche. Abundant molluscan fauna indicate lower Miocene age for these rocks, equivalent to mainland Vaqueros. Paleocurrent directions are again consistently to the north. Vaqueros sediments were generally derived from the same source as those of the Sespe.
A siltstone interval above the main Vaqueros sand interval, mapped as upper Vaqueros by Weaver et al. (1969) has been mapped as Rincon by Dibblee et al. (1998).

RINCON FORMATION

The Rincon Formation is generally a massive siltstone and claystone about 450 m thick with local yellow dolomitic concretions (Avila and Weaver, 1969; Dibblee and Ehrenspeck, 1998). In outcrop it is light brown to gray and generally weathers into rounded grassy slopes. The unit thins toward the south and west, where the lower Rincon contains several fossiliferous sandstone intervals up to 50 m thick.

The lower part of the Rincon, especially to the south, was deposited in quite shallow water, probably inner shelf. The upper (finer) part was deposited in deeper water, either outer shelf or basinal. In upper La Joya Canyon, transition from inner shelf to basinal deposition (Monterey) takes place within about 50 m stratigraphically, indicating a rapidly subsiding basin. These rocks were deposited during late Zemorrian and Saucian time, early Miocene.

MONTEREY SHALE

Conformably overlying the Rincon is a relatively thin (up to 250 m) section of Monterey shale (Avila and Weaver, 1969; Dibblee and Ehrenspeck, 1998). It consists of creamy-white to beige weathering siliceous shale and siltstone, and appears to be more clastic and less biogenic than similar rocks of the mainland. In outcrop, it is more resistant than the underlying Rincon and forms bold ‘reefs’ where it strikes out to sea east of Arlington Canyon on the north coast. It is moderately brittle and therefore fractures in a fashion similar to classic mainland Monterey outcrops.

This unit was included by Avila and Weaver (1969) in the Rincon Formation due to its late Saucian to early Relizian age. However, the lower Monterey in the Santa Barbara area is this age, and the rocks are lithologically similar to those outcrops, so Dibblee et al. (1998) mapped it as Monterey Formation.

Stratigraphically, the relationship between the Monterey and several clastic and volcanioclastic units (Santa Rosa Island Volcanics, Beechers Bay Formation) is very complex and needs further refinement. The Monterey either represents deposition during relatively quiescent times or deposition in a small basin or basins isolated from sediment input during a turbulent period of rotating tectonic blocks and active volcanism.

SANTA ROSA ISLAND VOLCANICS

This unit, consisting of basaltic volcanioclastics, flows and shallow intrusives, is newly named on the map by Dibblee, et al (1998). Weaver, et al (1969) included it in the San Miguel Volcanics because of presumed affinities to similar rocks on San Miguel Island. Additional work on this unit has been done by Avila and Weaver (1969), Weigand et al., (1998) and Dibblee and Ehrenspeck (1998). It is divisible into three members.

Making up the bulk of the Santa Rosa Island Volcanics is the volcanioclastic member, up to 500 m of thick-bedded to massive brown basalt breccia and coarse basaltic
sandstone. This member is well exposed on the main road across the top of the island, south of the Santa Rosa Island fault. It thins rapidly to the east and west, suggesting localized deposition. North of the fault it only crops out at the very west end of the island. The clastic member usually occurs within the Monterey shale.

In several areas, small fragments of pelecypods and gastropods are found, indicating marine deposition. Dibblee and Ehrenspeck (1998) suggest a shallow water depositional environment for the clastic member. However, association with the Monterey might indicate deep water deposition by some sort of fluidized flow, with mollusks transported from the shelf.

The intrusive member is found mostly south of the Santa Rosa Island fault, and consists of basaltic dikes, sills, and several highly irregular bodies generally intruded into Rincon or Monterey Formations. Several of these bodies exhibit prominent chill zones. Recent dating of the intrusive member yielded an age of 19 Ma (middle Saucian, Luyendyk et al., 1998) but rocks as young as Relizian have been intruded. Avila and Weaver (1969) infer a late Saucian to early Relizian age for this unit.

The extrusive member consists of local basalt flows, including probable pillows.

**BEECHERS BAY FORMATION**

The Beechers Bay Formation consists of a sequence of largely volcaniclastic sediments deposited in several submarine fan environments (Avila and Weaver, 1969; Nuccio, 1977; Nuccio and Woolley, 1998; Dibblee and Ehrenspeck, 1998). The lower Beechers Bay, newly defined by Dibblee and Ehrenspeck (1998), is made up of light brown to greenish-gray fine sandstone interbedded with gray to brown siltstone. The sand is generally rich in plagioclase and volcanic rock fragment and poor in quartz. Metamorphic rock fragments including blueschist and greenschist are also present. Bed thickness in both lithofacies ranges from a few cm to several m, and sand content generally increases upward in the section.

Soft sediment deformation features indicate a west-southwest paleoslope (Avila and Weaver, 1969). At least 270 m of this unit is exposed on the north side of the island, between Green and Soledad Canyons.

The upper Beechers Bay crops out on the northeast and southeast coast of the island, and consists of coarse to fine-grained volcaniclastic sediments (Nuccio, 1977; Nuccio and Woolley, 1998).

Conglomerate is generally composed of dacite or andesite, usually with a component of metamorphic rock fragments, most notably blueschist. Locally, conglomerate rich in basalt is found. The conglomerate is channelized to massive.

The sandstone is generally coarse dacite-andesite litharenite, with volcanic rock fragments comprising up to 95% of the framework. This sandstone is medium to very thickly bedded and can be quite tuffaceous. The siltstone is generally rhythmically bedded and highly tuffaceous. It resembles the shale of the Monterey Formation and is best exposed in the cliffs at the pier at Beechers Bay.

These facies were deposited in different areas of a submarine fan. Members A (oldest) and E (youngest) consist of conglomerate and interbedded tuffaceous pebbly sandstone deposited on the upper fan. Members B and D are coarse sandstone with occasional siltstone and channel conglomerate from the channelized portion of the mid-
fan. Member C consists of equal parts siltstone and sandstone with local channel conglomerate, deposited in interchannel areas of the mid-fan. A west-southwest average paleocurrent direction is consistent with that of lower Beechers Bay Formation.

A distinctive conglomerate west of Carrington Point containing basalt and dacite clasts as well as blueschist, greenschist, milky quartz, and a variety of other metamorphic and plutonic clasts has been mapped by Weaver et al. (1969) as San Onofre Breccia, and by Dibblee et al. (1998) as San Onofre Facies of the Beechers Bay Formation. As this conglomerate interfingers with the tuffaceous sandstone of member A, it may not merit a special designation.

<table>
<thead>
<tr>
<th>Facies</th>
<th>Description and depositional environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dacite-andesite and basalt conglomerate; coarse tuffaceous sandstone. Upper fan channels.</td>
</tr>
<tr>
<td>B</td>
<td>Feldspathic dacite-andesite litharenite; tuffaceous siltstone. Sand:silt = 10:1</td>
</tr>
<tr>
<td></td>
<td>Channelized upper mid-fan.</td>
</tr>
<tr>
<td>C</td>
<td>Tuffaceous siltstone; feldspathic dacite-andesite litharenite. Silt:sand = 1:1</td>
</tr>
<tr>
<td></td>
<td>Local dacite-andesite conglomerate. Mid-fan interchannel.</td>
</tr>
<tr>
<td>D</td>
<td>Dacite-andesite litharenite; dacite-andesite and basalt conglomerate.</td>
</tr>
<tr>
<td></td>
<td>Channelized upper mid-fan.</td>
</tr>
<tr>
<td>E</td>
<td>Dacite-andesite and basalt conglomerate; coarse tuffaceous sandstone.</td>
</tr>
<tr>
<td></td>
<td>Upper fan channels.</td>
</tr>
</tbody>
</table>

Table 1. Summary of Beechers Bay Formation facies and depositional environment.

Soft sediment features indicate a west-southwest paleocurrent direction, similar to that of the lower member. When contrasted with the southerly paleocurrent directions observed in the Sespe and Vaqueros Formations, these suggest that rotation of the Western Transverse Ranges was underway at the time of Beechers Bay deposition. An alternative explanation for the anomalous paleocurrent directions is a local source separate from the mainland.

QUATERNARY HISTORY

Several Quaternary deposits occur on SRI, including alluvium of the coastal plain and stream terraces, ancient and modern dune sand, and concretion-rich "drift" sand (Dibblee and Ehrenspeck, 1998; Woolley, 1998b). Occasional exposures of lithified beachrock or eolianite occur on several of the uplifted wave-cut terraces.

Up to 32 m of alluvial silt, sand and gravel were deposited in several of the large
canyons and on the extensive low (ca. 3-10 m) wave-cut surface, forming a coastal plain that rings much of the island. The chronology of deposition is poorly understood, but it appears to have started between 60-200 ka and continued until several thousand years ago.

The most notable aspect of the Quaternary geology of Santa Rosa Island is the presence of pygmy mammoth fossils. Mammoths arrived on the Northern Channel Islands at some point in the late Pleistocene. The discovery of fossil mammoth bones in the 1870s led to the belief (which persisted until a few decades ago) that a land bridge must have existed between the islands and the mainland. However, absence of many animals expected to be found on the island had a land bridge existed (e.g., coyotes, gophers, rabbits, deer) has caused that concept to be largely abandoned. Bathymetry is also such that no land bridge would be exposed even at lowstands of sea level, although the four islands have been connected several times into one large island, Santrosae. Therefore all animals native to the island must have arrived by swimming, flying, or rafting.

Modern elephants are excellent swimmers. Presumably mammoths were also good swimmers and could easily have navigated the ca. 6-km-wide channel between Port Hueneme and the island landmass during a lowstand of sea level. Over time competition for resources caused the mammoths to reduce their body size and become a new species, the pygmy mammoth (Mammuthus exilis). Late specimens of pygmy mammoth stood slightly less than 2 m high at the shoulder.

In 1994 the first complete skeleton of a pygmy mammoth was found by Tom Rockwell of SDSU west of Carrington Point, near the northeast part of the island, in dune sand. The remains, excavated by Larry Agenbroad and a team assembled by the NPS, has been dated at 12,840 ± 410 years old (Agenbroad, 1998), making it one of the youngest mammoths found on any of the Channel Islands. It is now on display at the Santa Barbara Museum of Natural History.

The dune in which the mammoth remains were found is part of the Carrington Point dune field, a stabilized late Pleistocene dune complex covering about 850 acres. It covers the ca. 125 m wave-cut surface to a depth of perhaps 50 m, and has migrated across the alluvium of the coastal terrace which was deposited on the younger wave cut surface now found at 3 to 5 m. The latest phase of dune formation appears to have been rapid, and may be related to overgrazing by mammoths, as discussed at Stop 15.

HUMAN HISTORY

Several workers including Orr (1968) and Berger (1980) have presented evidence for the coexistence of mammoths and humans on the island. Mammoths and humans come close to overlapping in terms of time, but to date there has been no widely accepted proof that they coexisted. While it is tempting to envision human hunters contributing to the extinction of mammoths on Santa Rosa Island, it is seems probable that mammoths died off due to reduced resources resulting from a drier, warmer climate as glaciers receded, which also resulted in rising sea-level and reduced land area. Perhaps someday we will find irrefutable evidence of man and mammoth together on Santa Rosa, but at this point the evidence suggests otherwise.

Santa Rosa was occupied by the Chumash people and their predecessors for over
10,000 years. In the 1960s, Phil Orr of the Santa Barbara Museum of Natural History, discovered an accidental human burial in Arlington Canyon on the north side of the island. The skeleton was dated by radiocarbon at about 10,400 years old (Orr, 1968), making Arlington Springs Man among the oldest human remains known from California.

Two distinct native American cultures have been described from the island. Orr called the oldest culture the Highlanders because their camps are found on the slopes of the highest peaks of the island, generally at elevations above about 200 m. They lived from 7,000-8,000 years ago and their economy was based mostly on vegetable products such as acorns; they made relatively little use of seafood. This suggests that the island was more heavily wooded during that period due to a climate slightly cooler and more moist than that of today.

The drying of the climate caused the woodlands to recede considerably, and around 4000 years ago the Highlanders moved nearer the coast to take advantage of abundant seafood. These people became the Chumash, and their descendants encountered Spanish explorers beginning in the 16th century. In 1542 Cabrillo described several villages containing several hundred people.

Cabrillo's name for the island is lost to history. Vancouver gave the islands their modern names in 1793; Santa Rosa was named after St. Rose of Lima. Rose, described as "the first flower of sanctity to bloom in the Americas", was born in Lima about 1586, and at age five made the vow of perpetual virginity. She became a nun at 15 and lived a life of mortification and penance until her death at the age of 31.

After removal of the Chumash in about 1815, the island was inhabited periodically by sea-otter hunters, who extinguished the otter population within a few decades.

The island was granted by the Mexican government to the Carrillo family of Santa Barbara in 1843, and in 1844 ranching operations were started by the American husbands of the two Carrillo sisters. The ranchers, Thompson and Jones, built a house (the location of which is unknown) and introduced sheep, cattle, and horses. The ranch apparently thrived but the business partnership did not, and by 1856 Thompson and Jones were in court with one another.

In 1858 the island was sold to the More family of Santa Barbara for about $24,000. The Mores built the existing ranch complex, several buildings of which may date from the late 1850s or early 1860s (two barns, two houses, and the pier are noted on an 1871 map). The More ranch was a sheep operation, and there are reports of as many as 60,000 to 100,000 grazing animals during this period. The two large iron tanks in front of the small barn at the ranch date from about 1876, when a crash in the sheep market necessitated a large-scale slaughter on the island. The tanks were used for rendering tallow.

The sheep ranch apparently had a significant impact on the island's landscape. Most of the large canyons exhibit geologically recent barrancas, steep- to vertical-sided stream channels entrenched into the alluvial terrace. Most of the large canyons on the island contain such barrancas. Causes and chronology of these features is not well understood, but a significant factor was probably severe overgrazing by sheep followed by flooding during one or more wet winters in the late 19th century. The earliest known photos of the island (1901) show the barranca system in place, but several barrancas which traverse the coastal plain cut through Chumash camps which were abandoned.
about 1500 AD (Orr, 1968). Downcutting and widening of these barrancas has slowed considerably since the end of sheep grazing.

A. P. More managed the ranch for much of this era; his tenure was tempestuous at times. In 1884 a Chinese cook with whom More had a disagreement packed his bags and walked to the end of the pier, threatening to leave the island. More followed him and shot and killed him as he was attempting to board a boat for Santa Barbara. At trial he claimed that the altercation had taken place over state waters and that the Santa Barbara County sheriff had no jurisdiction. The case was dismissed.

In 1901, Walter Vail of Los Angeles and J. V. Vickers of Tombstone, Arizona Territory, bought the island from More’s estate. The operation was changed from sheep to cattle. The Vail & Vickers partnership, now in its third generation, managed the ranch until summer, 1998.

The National Park Service purchased the island for inclusion in the Channel Islands National Park in 1986.

FIELD TRIP

The following road log will discuss some of the features to be viewed at several stops, and other items of interest between stops. Stops are numbered sequentially for the whole trip. For example, stop 14 is the first stop on day 3. Road conditions are unpredictable and we may not be able to access all desired stops. Therefore more stops have been discussed than we will probably make, in order to build in some flexibility.

DAY 1

Stop 1 Bluffs at the pier: Here is exposed a section of tuffaceous siltstone and sandy siltstone from member C of the Beechers Bay Formation. Note the rhythmic bedding in the fine grained rocks and ripple marks on exposed bedding planes. Also seen here are several channels filled with coarse sand and conglomerate. The main component of the conglomerate is dacite and andesite, characteristic of the Beechers Bay. Locally observed are beds containing basalt clasts. The siltstone was deposited in an interchannel environment on the mid- to outer-fan, while the conglomerates were deposited in channels. Of special note is a very large dacite boulder, several meters across, seen near the mouth of the House Creek.

Also well exposed here is the unconformity, here angular, between Miocene Beechers Bay Formation and Pleistocene alluvium, deposited on a low wave-cut surface. This alluvium forms a coastal plain which rings most of the island and is present as stream terraces in most of the large canyons.

The pier was built by the Mores around 1860. It had been until this year to load and unload livestock and supplies. The cattle boat, Vaquero II, was based in Santa Barbara and carried about 100 animals on the five-hour trip to or from Port Hueneme.

DAY 2

Between the ranch and Stop 1 at Black Mountain we will be traveling
Figure 3. Drainage map of Santa Rosa Island, showing the four major watersheds and their divides. Note aligned and deflected canyons near middle of the island (along Santa Rosa Island fault). Also shown are some ranch roads and island locations.
downsection, from Beechers Bay member C to member B.

**Stop 2 Santa Rosa Island fault at Black Mountain:** Here we see the surface expression of the Santa Rosa Island Fault. To our east, its trace is clearly marked by aligned canyons and vegetation changes. North of the fault, bedrock is Beechers Bay coarse sandstone which supports a chaparral plant community. South of the fault are grassy hills underlain by Santa Rosa Island Volcanics.

Far to the east, the fault appears to have a component of vertical movement, north side up, as indicated by a fault line scarp. To the west the south side appears to be uplifted slightly and a series of aligned saddles mark the trace of the fault. On the map, many of these drainages are aligned, and there is some evidence that several of these streams have been beheaded or captured due to lateral movement on the fault. The peak immediately to the north across the fault is Black Mountain, the highest point north of the fault (393 m). The road along the south slope of Black Mountain lies within the fault zone. Note the highly fractured Monterey shale or Beechers Bay siltstone, complete with some tight folds.

**Stop 3 Santa Rosa Island Volcanics:** Here we see the coarse clastic member of the Santa Rosa Island Volcanics. This section consists of thickly bedded basaltic coarse sandstone and breccia. The unit locally contains fragments of seashells, indicating marine deposition. Proximity to the Monterey Formation suggests deposition in deep water, possibly as debris flows. Occurring locally within these bedded units are local basaltic flow rocks.

Between Stops 3 and 4, we see several items of note. To our north, note the extensive wave-cut surface at an elevation of about 125 m. Depending upon rates of uplift, this surface could be as old as 1 Ma. If the weather is clear, this road provides a good view of San Miguel Island to the northwest.

Several stands of live oak along this road are relict from glacial climates when Santa Rosa Island was somewhat cooler and moister than today. Oaks and pines were more widespread and there is evidence that redwood and Douglas fir grew here as well. The largest stand, south of the road, is restricted to Monterey shale. Exposed root systems of some of these trees testify to the amount of soil erosion that has taken place in the recent past.

At the end of the paved road to our northwest, the flat topped peak is the highest point on the island (484 m). It was the site of a Air Force radar installation during the Cold War, the base camp for which was at Johnson's Lee (Stop 6).

The unpaved road we have been on is the Standard Oil road, built in 1932-33 prior to drilling the first exploratory oil well on the island. Standard's vehicles were the first motorized vehicles on the island. It was not until after World War II that the ranch had non-equine transportation. The well was drilled to a total depth of 6298' and encountered no hydrocarbons, but did penetrate a thick section of conglomerate below the South Point sandstone containing clasts of siliceous volcanics similar to the Poway conglomerates. The well site is about 300 meters to the west of the intersection of these two roads.

A discussion of the petroleum exploration history of the island can be found on
the back of the geologic map of Santa Rosa (Dibblee et al., 1998).

**Stop 4 Army Camp Road:** From this point, and along the road north of this point, we see good exposures of the lower to middle Miocene section, including Vaqueros, Rincon, Santa Rosa Island Volcanics, and Monterey Formations. The large canyon to our east is La Jolla Canyon, in the bottom of which are exposed the upper sandstones of the Vaqueros Formations. These are beach and shallow marine sandstones.

Above the Vaqueros lies the Rincon Formation. Here the lower Rincon consists of shallow water siltstone and mudstone with occasional fossiliferous sandstone beds several meters thick. The road passes through several of these fossil beds. The upper Rincon here consists of siltstone and mudstone deposited in deeper water. Above the brown Rincon siltstone and mudstone lies the light colored Monterey shale. This siliceous shale appears to have a significant clastic component and is Saucesian and Relizian in age, equivalent to the lower Monterey along the Santa Barbara coast.

On the slope to our south, within the white Monterey, is visible a brown layer of Santa Rosa Island volcanics. This is the elastic layer made up of coarse basaltic sandstone and fine-grained breccia. Note the degree to which the unit has thinned compared with the vicinity of Stop 3.

Along the skyline to our north, you can see the Soledad anticline, the structure tested by Standard in 1932.

**Stop 5 Lighthouse Road:** Exposed in the road cut here is South Point sandstone to the south juxtaposed across a fault with Sespe and Vaqueros formations to the north. This fault can be visually traced to the east-southeast using vegetation changes.

This is the only Sespe exposure visible on this loop. On Santa Rosa, the Sespe thins and fines to the east. It is rich in pebble and cobble conglomerates to the west at Bee Canyon, while east of San Augustine Canyon, the Sespe appears to transition into a marine deposit. Also to the west, the contact between the Sespe and the overlying Vaqueros is clearly transitional, recording a marine transgression. At this stop we see a fairly abrupt contact between the pinkish Sespe below and the yellow Vaqueros above.

**Stop 6 Johnson's Lee:** This is the best anchorage on Santa Rosa Island, although remote from Santa Barbara. One of the most recent Chumash camps was found here. In 1948, the United States Air Force built a camp here as part of their Distant Early Warning system. The camp housed 300 people and operated a radar station on the highest peak on the island, and was active until the early 60's. When the NPS bought the island in 1986, their plan was to have park headquarters here due to the good weather. However, logistical considerations as well as lack of water resulted in relocation of the headquarters to the ranch at Beechers Bay. In about 1994 the remaining barracks, which were in a state of considerable disrepair, were bulldozed and buried by the Park Service. Remains of the Air Force pier can be seen.

Outcropping along the beach is South Point Formation. Road conditions may dictate that we turn around here, so see Stop 7 for a brief discussion of these rocks.

**Stop 7 Little La Jolla Beach:** Here we see good outcrops of the middle Eocene South Point Formation, a submarine fan complex deposited in the Eocene forearc basin. The
bedding style here is characteristic of South Point everywhere on the island. Note the load structures in the sand, dish structures and soft sediment deformation features in the siltstone. Also visible in the South Point are spherical calcite-cemented concretions that weather out of the sandstone.

This unit is correlative with the Jolla Vieja Formation on Santa Cruz Island which contains probable Poway conglomerates related to those in San Diego County (Abbott et al., 1983). No conglomerates are exposed on Santa Rosa Island, but two of the exploratory wells penetrated several hundred meters of probable Poway conglomerate at the base of the South Point Formation. Also exposed here is a basaltic dike which is probably correlative with the Santa Rosa Island Volcanics.

**Stop 8 Cozy Dell Formation:** On the west side of Wreck Canyon, the road traverses a section of middle to upper Eocene Cozy Dell Shale, a deep water mudstone and shale. This is probably the basinal equivalent of the South Point Formation. This unit typically weathers into round, grassy slopes. It often has yellow dolomitic concretions about 10 - 50 cm thick, extending laterally for several meters, and local gypsum crystals.

Wreck Canyon is so named because in 1894 a passenger ship, the Crown of England, went aground here. A part of a mast from the ship and remains of a boiler from a salvage operation can still be seen on the rocks.

**Stop 9 Santa Rosa Island Volcanics, intrusive member:** This roadcut exposes several thin interconnected sills intruding Rincon mudstone. This represents the extreme eastern edge of body of intrusive material which thickens to the west.

**Stop 10 Clapp Springs:** One of the largest intrusive bodies of the Santa Rosa Island Volcanics crops out here, discordantly intruding fossiliferous Rincon siltstone and sandstone. It thins and pinches out to the east, and near its eastern edge very clear chill margins are seen. This and related bodies extend westward in a band broken by faulting through the upper reaches of San Augustine Canyon for over 2000 m.

Of note here is the presence of Clapp Springs. Legend has it that it was named by early (and presumably short-lived) cowboys who claimed the sweet water from this spring was a cure for a certain venereal disease. The water here is so superior to most other island water that some island old-timers believed (some still do) that the aquifer is somehow connected to the Sierra Nevada.

The spring occurs at the base of the intrusive body, where it is in contact with the Rincon. The flow is remarkably constant, varying little with rainfall, possibly due to low permeability of the intrusive rock.

**Stop 11 Santa Rosa Island fault:** The east-west trending, left-lateral Santa Rosa Island fault dominates the structure of the island. Here the fault is clearly visible. To the east and west drainages are aligned along the fault, and the main drainage to the west, Water Canyon, as well as several minor drainages, are offset along the fault. East of the road is a ca. 10 m high south-facing scarp, indicating a component of dip slip, although to the west dip slip appears to be south side up. To the west a clear lithology change is apparent across the fault, accompanied by different vegetation.

High on the west bank of Water Canyon and perhaps 100 m north of the fault is a
small body of fine-grained chlorite-epidote schist which appears brick red in outcrop, similar in many respects to the Santa Cruz Island Schist. This is the only known exposure of basement rock on the island. Its relationship to surrounding Beechers Bay sandstone is unclear. Proximity to the Santa Rosa Island fault makes it tempting to consider it a fault sliver along that fault. However, in the west wall of Water Canyon the schist appears to overlie sandstone and therefore may be some sort of slide block emplaced during Beechers Bay deposition. (Dibblee and Ehrenspeck, 1998).

Also note in Water Canyon the barranca, representative of others on the island. Historic evidence shows the steep-sided barrancas had assumed their present form by 1901, partially as a result of several cycles of overgrazing by sheep, drought and floods. Widening and downcutting had slowed considerably from 19th century rates, presumably as a result of the transition from intensive sheep grazing to moderate cattle grazing. A predecessor system is evident in some canyons; the Water Canyon barranca cuts down into bedrock 15-20 m at its mouth.

Stop 12 Black Rock: The rock at this point is Beechers Bay member C or D conglomerate deposited in a large channel, the central portion of which consists almost entirely of basaltic detritus. The basaltic component appears to have been emplaced very rapidly, possibly a result of a lahar or volcanic debris flow. Evidence includes large-scale load features where underlying tuffaceous sandstone has been squeezed up into the basaltic channel body, then eroded from underneath by wave action forming several sea caves. In other places coarse sandstone has been truncated by downcutting of the channel.

Within the basaltic part of the channel is a mass of apparently vesicular basalt 5 to 10 m across, with geometry suggesting pillows. This may have been transported from shallow water as an intact block, or may indicate a local source for some of the basaltic material.

The northern margin of this channel, not visible from this point, consists of interbedded coarse tuffaceous sandstone and dacite-andesite conglomerate.

To the south, on the slope above the road, is the main stand of Torrey Pines on the island. This is one of two stands in the world, the other being at La Jolla near San Diego.

Stop 13 Water Canyon: These rocks are transitional between Beechers Bay members C (interchannel deposits from the mid-fan) and D (channelized part of the mid-fan). Many sedimentary features are visible here including small-scale channeling, graded bedding and layers of ash or pumice. The sandstone coarsens to the south, into member D volcaniclastic sandstone.

DAY 3

Stop 14 Carrington Point: Exposed in the seaciffs around Carrington Point are two distinct facies of the Beechers Bay Formation. Southeast of the point is exposed a thick section of tuffaceous coarse sandstone and conglomerate of member A, which has a high component of ash and contains many clasts of pumiceous vitrophyre.

Interfingering with the sandstone at the very point and cropping out west of the point is a thick section of conglomerate containing clasts of basalt, dacite, and most
notably blueschist, greenschist and other metamorphics and plutonics. This unit has been mapped by several workers as San Onofre Breccia due to presence of metamorphic detritus. However the entire Beechers Bay Formation on Santa Rosa Island contains small amounts of blueschist.

Is this simply a spectacular exposure of a basalt-rich Beechers Bay channel, or does it merit special designation as San Onofre Breccia? What is the significance of the blueschist detritus in the Beechers Bay sediments?

**Stop 15 Carrington Point dune field:** Covering the wave-cut surface here at an elevation of about 125 m, and several lower terraces, is an extensive stabilized dune field. Several periods of dune formation are represented, the latest of which is probably late Pleistocene in age. Dunes cover about 800 acres and sand thickness may exceed 50 m.

It was in these dunes that the 1994 mammoth discovery was made. It was located in sand under a thin paleosol which was in turn overlain by more dune sand. As indicated by the age of the mammoth (12,840 ± 410 years) much of the dune field was formed after that time, during a period of rising sea level. This suggests rapid dune building, perhaps due to rapid erosion resulting from overgrazing by mammoths. The last few mammoths, competing for a shrinking resource base, stripped the island of vegetation. One or more floods would have caused rapid erosion on the denuded island, supplying large volumes of sediment to the beaches, along which the sand fraction was worked by prevailing winds. The sand was deposited on headlands at the downwind end of these beaches, such as Carrington Point. The paleosol suggests that this sequence of events took place more than once, ultimately leading to extinction of the mammoths. An analogous dune field occurs at Skunk Point, at the east end of the island.

A thin veneer of this sand extends south from Carrington Point across the 125 m terrace. In these sands are found numerous round red iron-rich concretions about 2 cm in diameter. A recent x-ray diffraction semi-quantitative mineralogical analysis by Weigand (1998, pers. comm.) revealed that these concretions are composed of quartz (55%), plagioclase (18%), magnetite (8%), clay (7%), K-feldspar (6%), hematite (4%), and goethite and hornblende (1%). Johnson (1980) has suggested that these formed in the A soil horizon under acidic conditions, probably due to the presence of a widespread pine forest. This is consistent with a cooler, moister climate during late Pleistocene glacial periods, when oak, pine, and even redwood and Douglas fir flourished on the island. Relict stands of several types of oak and pine are still found on the island, including closed-cone pine on the north slope of Black Mountain, adjacent to the concretionary sands.

**Stop 16 Lobo Canyon:** Lobo Canyon is cut into Beechers Bay member B, a sequence of thickly bedded coarse sandstone and interbedded white tuffaceous siltstone with a sand-silt ratio of about 10:1. The sandstone is composed of quartz (16%), plagioclase (An 40 to 50, 30%), volcanic rock fragments (dacite and andesite, 52%), and metamorphic rock fragments, including biotite schist and rare glauconphane schist.

Where the road crosses the canyon is a block slide landslide formed where northeast dipping bedrock daylights in the west wall of the canyon. A 27 acre block has moved about 30 m northeast, presumably on a slide plane of tuffaceous siltstone.

The headward scarp is characterized by a series of linear rifts, one of which is
visible from the road east of the canyon. An east-west trending fault, visible in theoadcut about 3/4 of the way into the canyon, determined the location of the southern rift. The leading edge of the slide occurs in Lobo Canyon and an east-flowing tributary north of the road, and consists of fractured and shattered sandstone, including several blocks up to 5 m across which have tumbled into the canyon. The leading edge is also heavily wooded; the shattered bedrock apparently providing a good place for seedlings to sprout and thrive.

The very leading edge of the slide is characterized by a sharp, small-scale anticline as well as a year-round spring. The slide also dammed Lobo Canyon as evidenced by an area of ponded sediment upstream from the slide.

Several factors point to the recency of this slide, and anecdotal evidence suggests that local Chumash witnessed the slide move during a large earthquake shortly before they were removed to the mainland. The slide probably occurred during the Dec. 1812 Santa Barbara Channel earthquake (M=6.5-7.5).

SELECTED REFERENCES


Avila, F. A. 1968, Middle Tertiary stratigraphy of Santa Rosa Island, California, [Unpublished M.A. Thesis]: Santa Barbara, University of California, 87 p.


California: Geol. Soc. America, Cordilleran Section, 91st ann. meeting, program with abstracts, v. 7, #5, p. 11.


Kew, W. S. W., 1927, Geologic sketch of Santa Rosa Island, Santa Barbara, California: Geol. Soc. of America Bull., v. 38, n. 4, p. 645-653.


Orr, P. C., 1968, Prehistory of Santa Rosa Island: Santa Barbara, California, Santa Barbara Museum of Natural History, 253 p.


