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Lobo Canyon Landslide: Santa Rosa Island, California

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Abstract. The Lobo Canyon Landslide, located in Lobo Canyon on the northeast coast of Santa Rosa Island, California, is a complex block slide. Its features include a series of linear pull-apart cracks or rifts defining the slide's headward area, and a zone of fractured bedrock and rockfalls, making up the zone of accumulation. The slide body has remained largely intact.

The southern boundary of the slide is determined by the location of a small fault: northern and eastern edges by northeast dipping bedding planes exposed in canyon walls. This feature has been discussed as the fault that generated a M = 7.0–7.5 earthquake on 21 December 1812. While it is clearly a landslide, it probably was initiated by an event of this magnitude and could have occurred during the 1812 quake.

Keywords: Santa Rosa Island; California Channel Islands; block slide; landslides caused by earthquakes; 21 December 1812 earthquake (Santa Barbara).

Introduction

The Lobo Canyon Landslide is a block-glide type slide occurring in Lobo Canyon (Cañada Lobos), Santa Rosa Island, California.

Santa Rosa Island (Fig. 1), 1 of the 8 islands offshore Southern California, lies 30 mi SSW of Santa Barbara. It is the 2nd largest of these islands at 55,000 a. Geologically, Santa Rosa is made up of a complexly faulted sequence of Eocene through Miocene sandstone,

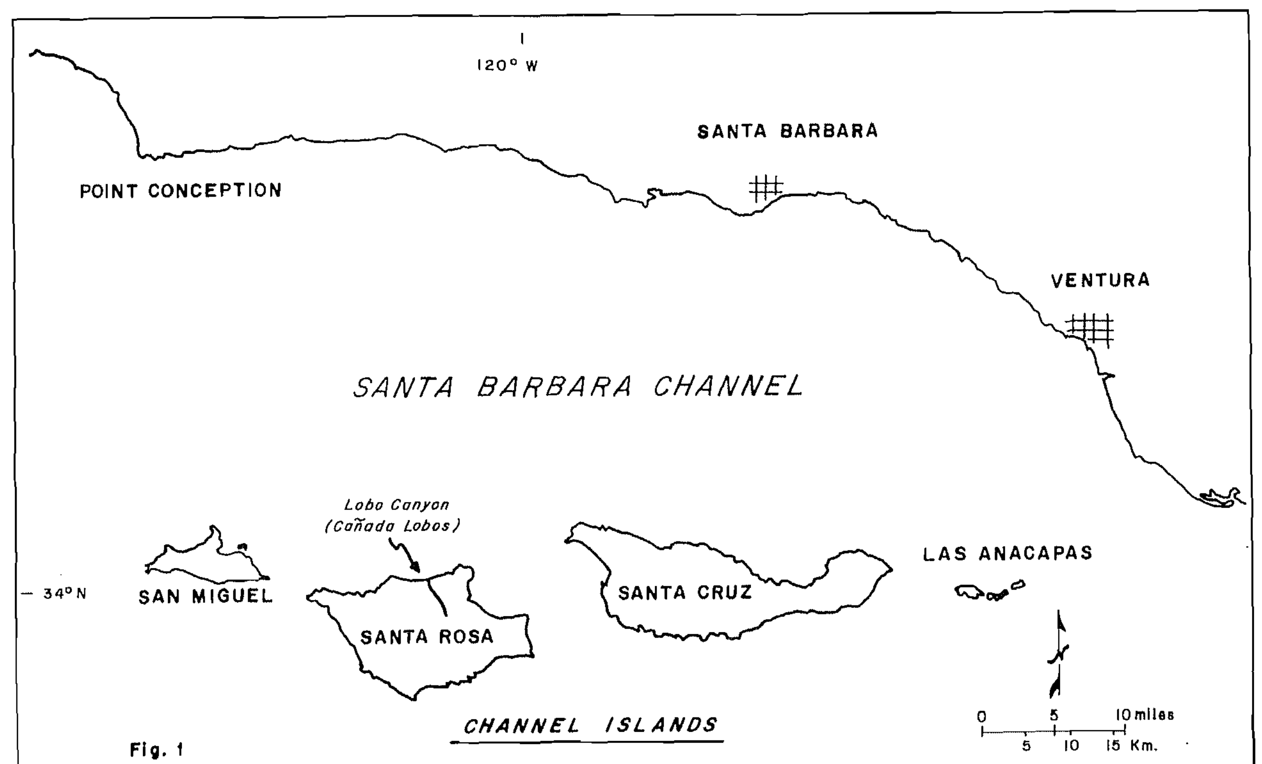

Figure 1. Location of Santa Rosa Island.

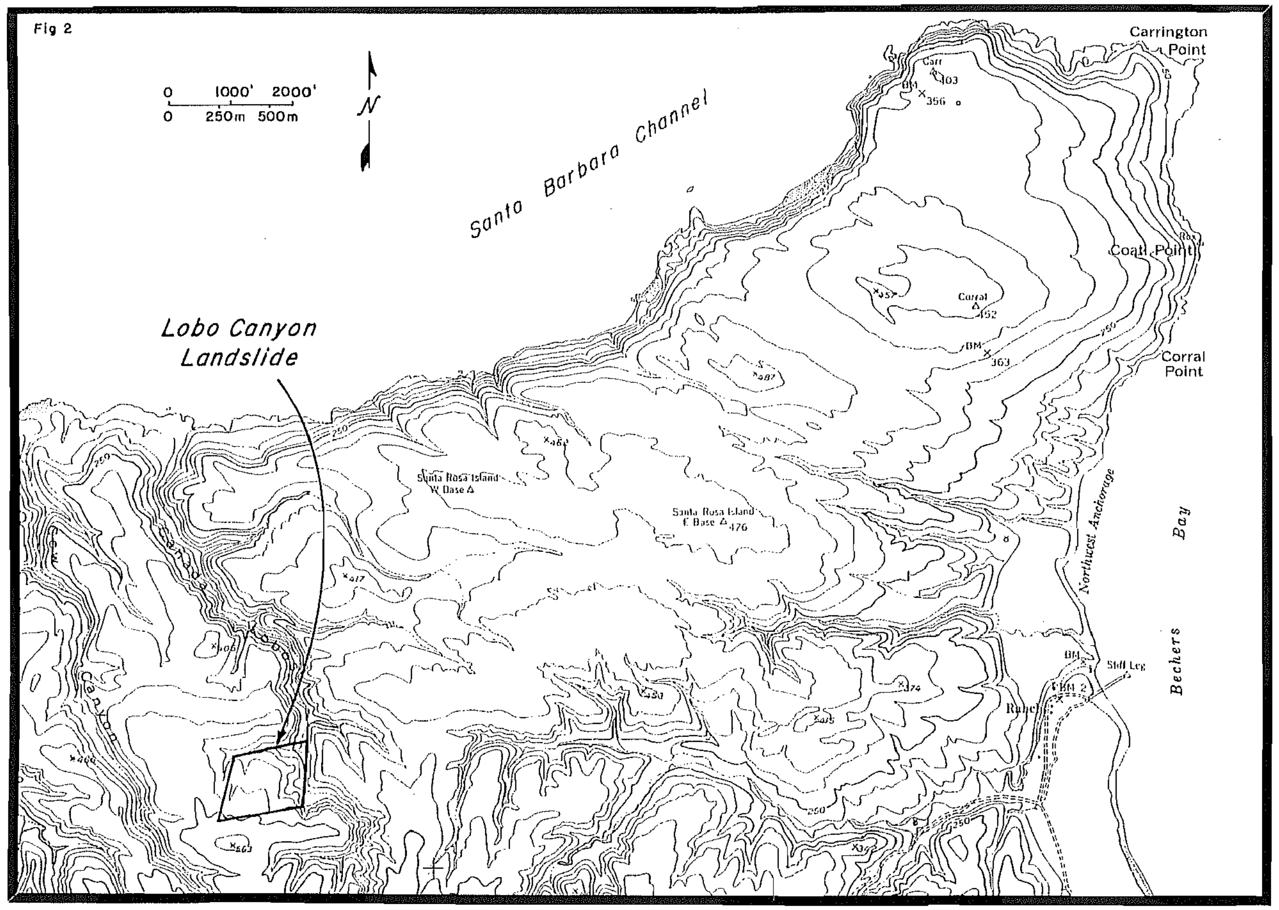

Figure 2. Lobo Canyon (from U.S. Geological Survey 7.5 min quad— Santa Rosa Island–north).

siltstone and conglomerate. The island has been used for ranching since the 1840s, and is currently operated by the National Park Service as a unit of the Channel Islands National Park.

Lobo Canyon, located on the northeast part of Santa Rosa Island (Fig. 2), is a major northward draining canyon, the mouth of which lies about 5.5 km (3.4 mi) west of Carrington Point. The slide lies on the west side of the canyon about 1.8 km (1.1 mi) inland (south) from the mouth. The main road across the north side of the island (Smith Highway) traverses the slide for a distance of approximately 610 m (2,000 ft) as it climbs the west wall of Lobo Canyon.

Description of Landslide

Headward area

The slide is a complex block-slide and involves about 27 a. Elevation at the toe of the slide is about 76 m (250 ft) and at the top of the slide is 152 m (500 ft).

Bedrock involved in the slide is a coarse-grained volcaniclastic sandstone, showing thick to massive bedding with local large scale (> 10 m; 30 ft) channeling and cross-bedding. This unit was assigned the Member B of the Beechers Bay Formation by Nuccio (1977), and the Blanca Formation by McLean et al. (1976). Weaver et al. (1969) referred these rocks to the Beechers Bay member of the Monterey Formation. These sands were deposited in a channelized mid-submarine fan environment during Relizian or early Luisian (middle Miocene) time, about 15 million years ago.

The slide (Fig. 3) occurred where beds dipping 10–20° in an east to northeast direction were truncated by Lobo Canyon, whose western wall now slopes up to 50°. The sliding apparently took place along a bedding plane surface. The slide plane itself is not exposed. Depth to the slide plane could not be determined, but exceeds 8.5 m (28 ft) at the head of the slide, and varies with topography.

It is likely that the failure occurred along siltstone interbedded with the Member B sandstone. These fine-grained beds seen occasionally in Member B (Nuccio [1977] cited a sand/siltstone ratio of 10:1 for this member) are described as tuffaceous sandy coarse siltstone. They range in thickness from 0.3 to 1.8 m (1 to 6 ft). They contain abundant volcanic rock fragments and minerals in a matrix that has been largely altered to clay.

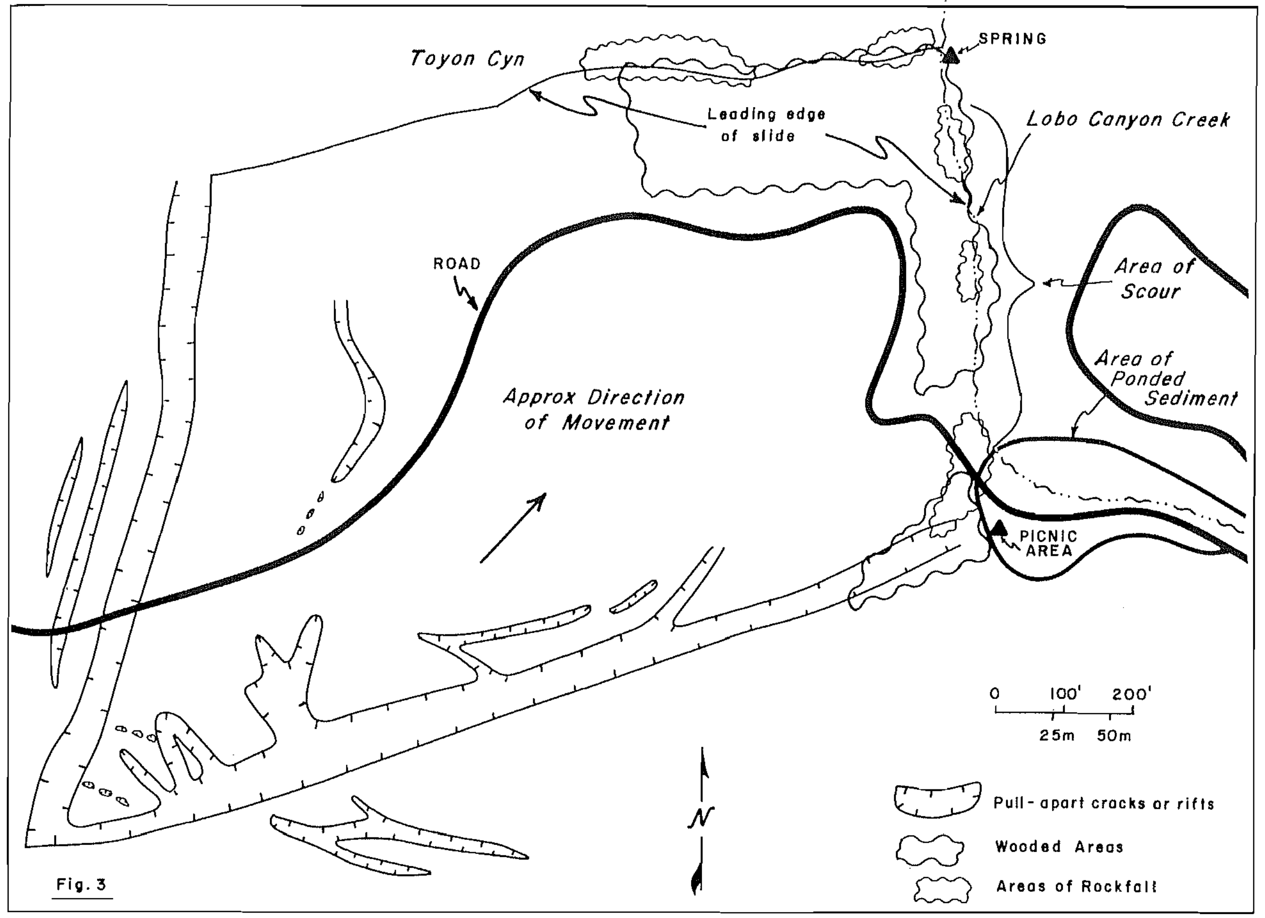

Figure 3. Sketch map of Lobo Canyon landslide.

The most notable feature of the slide is the complex system of mostly linear pull-apart cracks or rifts that bound the slide on the south and west and thus form a complex headward scarp. On the west edge of the slide, up to 3 parallel cracks occupy a zone whose maximum width is about 44 m (145 ft). These cracks trend N 14° E for a distance of 305 m (1,000 ft) and have a cumulative pull-apart of up to 23 m (75 ft). The widest of these cracks is up to 18 m (60 ft) wide.

The walls of the cracks are vertical, suggesting fracturing and subsequent lateral movement of the slide block. Original depth of the cracks was not determined, but today they range in depth from 1 to 5 m (3 to 16 ft), having been filled with sediment and soil. Along the bottoms of the cracks grow scrub oak (*Quercus dumosa*) and coyote bush (*Baccharis pillularis*).

The southern rift system shows about the same amount of pull-apart movement as that bounding the slide to the west, but is more complex. The main crack in this system trends about N 70° E and extends about 457 m (1,500 ft), terminating under the area of ponded sediment in the bottom of Lobo Canyon, at the Picnic Area. (There was formerly a picnic table here that was the traditional destination of outings from the ranch, before motorized transportation.) The 2 crack systems intersect at approximately a 60° angle at the highest point, or apex, of the slide.

The main crack varies in width from 11.5 to 22 m (38 to 72 ft), and in depth from 2 to 8.5 m (6 to 28 ft). A series of secondary cracks occur along the western 1,000 ft of the main southern rift, ranging in trend from N 70°E through nearly E–W to about N 25° W. These lie both north and south of and are narrower and shallower than the main crack.

The area within about 152 m (500 ft) of the apex of the slide has been extensively fractured and rifted. Post-slide erosion and sedimentation has made resolution of fracture geometry in this area difficult. Along the south rift system, the slide has dropped in elevation 0–5 m (0–16 ft) relative to original ground level. No elevation change was observed along the western boundary of the slide. The body of the slide has remained relatively intact, with some minor cracking, largely obscured by erosion.

Zone of accumulation

The zone of accumulation, or toe of the slide, occurs in 2 canyons north and east of the rift zone. The eastern boundary or toe of the slide coincides with the Lobo Canyon Creek for a distance of about 228 m (750 ft), downstream from and north of the Picnic Area. The northern toe of the slide lies in the informally named Toyon Canyon, an east-trending tributary to Lobo Canyon that flows into it at the northeastern apex of the slide, approximately 228 m (750 ft) north of the Picnic Area. Toyon Canyon bounds the slide for a distance of about 332 m (1,090 ft).

Several notable features mark these leading edges of the slide. The entire length of the slide front is characterized by fracturing of the slide block, the density of which varies considerably. In areas where the slide plane is exposed, bedrock is fractured into pieces as small as 2.5 cm (1 in.) across. Above the slide plane, bedrock is commonly broken into boulders from 1 to 3 m (3 to 10 ft) in size; pieces up to 15 m (49 ft) across were observed. Blocks of bedrock have moved relative to one another, resulting in highly variable dips.

There are several areas where large chunks of bedrock up to 4.6 x 5.5 m (15 x 18 ft) in size have tumbled off the front of the slide into 1 of the bounding canyons. This phenomenon is best observed at the Picnic Area, where the road starts up the west wall of the canyon. Large chunks of bedrock have likewise fallen elsewhere in the canyon, especially near the toe of the slide, and for at least 110 m (360 ft) up Toyon Canyon.

One of these rockfalls apparently dammed Lobo Canyon Creek just downstream from the Picnic Area. The wide, flat area in the bottom of Lobo Canyon, including the Picnic Area and extending about 250 m (820 ft) upstream, is the result of sediment ponding behind this rockfall dam. Immediately below the dam, the canyon has generally been scoured down to bedrock all the way downstream to the northeast apex of the slide, indicating a sediment-starved creek due to sediment having been deposited above the dam.

The fact that some of the bedrock boulders lie atop the ponded sediment might suggest several episodes of movement on the slide. Alternatively, these boulders may have fallen after the slide movement, due to weathering or subsequent moderate ground shaking insufficient to reactivate the slide.

About 46 m (150 ft) up Lobo Canyon (southerly) from the extreme toe of the slide, just above the creek bed on the west side of the canyon, is exposed a zone of intensely fractured bedrock in a matrix of soil. This zone may represent the slide plane. On the east side of the creek at this point, the bedrock is almost completely unfractured.

Downstream from this exposure, water was observed standing in pools. This observation was made in late October, normally the driest time of year on Santa Rosa Island. Upstream, the creek was dry. Between this point and the toe of the slide, the creek flows across the slide plane, as the heavily fractured zone is visible on the east side of the creek.

In the vicinity of the northeast apex, or extreme toe of the slide, several slide-related phenomena were noted. A pronounced small-scale fold occurs at the toe of the slide, at the confluence of Toyon and Lobo Canyons. Beds roll over from approximately horizontal to N 70° W, 68° N in a distance of about 4 m (12 ft).

A spring flowed at an estimated rate of 38–76 l/min (10–20 gpm) from the creek bottom, due to groundwater flowing down the impermeable slide plane and surfacing here, the lowest elevation on the plane. A group of phreatophytic plants grows on the slopes just above the toe.

Another notable feature of this slide is the thick concentration of trees, including live oak (*Quercus agrifolia*) and Toyon (*Heteromeles arbutifolia*) along the eastern and northern boundaries of the slide (zones of accumulation). These groves contrast with the virtual absence of trees immediately upstream and downstream from the slide. It appears that disrupted ground along the slides leading edges provided a favorable habitat for seedlings to sprout and grow. Water surfacing along the slide plane may have aided their growth. If presence of these trees is due to the slide, then the maximum age of the trees might indicate a minimum age for the slide, assuming one episode of sliding.

Causes

The failure surface for the Lobo Canyon slide is 1 or more bedding planes in the Beechers Bay Formation sandstones that dip 10–20° in an east to northeast direction and are exposed in the western wall of Lobo Canyon, which slopes toward the east up to 50°.

A small fault visible on the east wall of Lobo Canyon appears to be aligned with the main south rift of the slide, and may be the determining factor in the location of that pull-apart feature. The fault trends N 76° E, and a zone approximately 2 m (6 ft) wide shows excellent horizontal slickenslides. Total offset could not be determined, but is not large at this point, as similar Beechers Bay Member B facies occur on both sides of the fault. Its westward extension could not be located in Cow Canyon, 305 m (1,000 ft) to the west. However, Weaver et al. (1969) mapped this unnamed fault as dying out just to the west of Cow Canyon and extending at least 4 km (2.5 mi.) easterly into Beechers Bay with offset increasing to the east.

Slide movement appears to have been relatively sudden. Discussions with ranchers on the island (Al Vail and Bill Wallace 1993, per. comm.) indicate no movement has taken place on the slide since the road was constructed across it in the late 1940s.

This evidence of sudden movement is consistent with an earthquake-generated slide. Keefer (1984), in a discussion of landslides caused by earthquakes, attributes this type of landslide ("rock block slide") to events of magnitude 5.0 or greater; they more often occur beyond magnitude 6.5.

It is proposed here that strong ground shaking due to a nearby earthquake of a magnitude greater than 6.5 triggered the Lobo Canyon Slide. The location of the slide was determined by at least 2 factors: (1) presence of the westerly-trending fault that formed the southern boundary of the slide; and (2) northeast dipping beds that daylight in both Lobo and Toyon Canyons.

Clear visibility of many landslide features, and continuing effects on nearby plant communities as well as the hydrologic regime in Lobo Canyon, all suggest occurrence of this landslide in the very recent geological (or even historical) past.

Relation to 1812 Earthquake

Authors (Orr 1968; Dailey 1990) have referred to the Lobo Canyon Slide as the "Lobo Canyon Fault," and have described it as surface rupture at the epicenter of a large earthquake that occurred in December 1812. On the 21st of that month, the quake struck the Santa Barbara area, damaging missions at Ventura, Santa Barbara, Santa Ynez, and Lompoc. Hamilton et al. (1969) listed the Rossi-Forel intensity of that quake as X (maximum intensity) and estimated the magnitude at 7.0. Norris and Webb (1990) claimed a magnitude of 7.5 for the earthquake.

While the Lobo Canyon feature is clearly not a fault, it probably occurred during strong ground shaking due to a large earthquake similar to the 1812 event. Descriptions of falling rock and panicked native islanders fleeing to the mainland missions from Santa Rosa Island after the 1812 earthquake (Orr 1968) lend some credence to an 1812 date for the Lobo Canyon slide.

Radiocarbon dating of the deepest soil horizon within the rift zones, and tree-ring dating of the trees associated with the leading edges of the slide, could help in determining the age of the slide.

Other Slides

A brief survey of Lobo Canyon and Cow Canyon, to the west, revealed several other apparently recent landslides. Most notably, approximately 1.6 km (1 mi) upstream from the Lobo Canyon Slide on the west side of the canyon, lies a slide with several features analogous to the Lobo Canyon Slide. This slide covers about 10 a. and is characterized by a pull-apart crack or rift significantly wider and deeper than the Lobo Canyon Slide. The crack trends approximately N 30° E, and is up to 30 m (98 ft) wide and 15 m (49 ft) deep, with full-sized live oaks growing in it. It widens to the northeast, towards the bottom of Lobo Canyon. This feature appears to have formed in the same manner as the Lobo Canyon Slide, probably at the same time.

Several other slides, more heavily modified by erosion, were noted in Cow Canyon.

Conclusions

The Lobo Canyon Landslide is an excellent example of a block-slide. Its notable features include the following:

1. A complex system of pull-apart cracks or rifts bounding the slide to the south and west, comprising the headward scarp.
2. The east and north boundaries of the slide lie in Lobo Canyon and its east-flowing tributary, Toyon Canyon, respectively. The leading edges of the slide are marked by a zone of fractured bedrock and rockfalls. One of these rockfalls has dammed Lobo Canyon Creek, as evidenced by an area of sediment ponded upstream from it. Also seen at the toe of slide is a spring and associated phreatophytic plants.
3. The slide plane is unknown but is probably a clay ridge siltstone interbedded with Beechers Bay Formation sandstones. These beds dip 10–20° in an east to northeast direction and daylight in the western wall of Lobo Canyon.

This slide had previously been discussed as a fault scarp due to the 21 December 1812 earthquake. This type of landslide is consistent with earthquakes of magnitude > 6.5, and may have been caused by the 1812 event.

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Natural Erosion of Fossil Root Concretions in the Caliche Forest, San Miguel Island, California, 1984–1991

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Abstract. Extensive calcareous accumulations (caliche) are unique geologic features of several of the California Channel Islands. Root-cast or root-sheath caliche was produced from vegetation that was buried by sand dunes up to 17,000 yr ago. On San Miguel Island, one large area of exposed stalk caliche, known as the Caliche Forest, attracts a substantial and growing number of visitors to Channel Islands National Park each year. The Caliche Forest has been exposed due to wind erosion and is susceptible to damage from continued natural erosion and from human disturbance, including focused sonic booms from military aircraft and space vehicle launches. To document natural rates of erosion of stalk caliche, we made photographs periodically of identified plots in the Caliche Forest from 1984 through 1991. Tall stalks, and those with thin appendages, eroded by 35–70% during this period, primarily from wind and sand abrasion and from weakening of the bases of stalks as surrounding substrate was blown away. Short, squat caliche stalks that lacked appendages eroded by 10% or less during the same period. Most of the stalks in the Caliche Forest will probably disappear during the next several decades due to continued erosion by wind (the dominant abiotic force at San Miguel Island) and rain. Continued natural revegetation of the island's landscape will also slow the emergence of buried caliche stalks. Focused sonic booms might periodically accelerate natural erosion of fragile stalks, but it is not likely that they will cause catastrophic destruction of the Caliche Forest.

Keywords: Caliche; California Channel Islands; San Miguel Island; sonic boom.

Introduction

Several of the California Channel Islands, including San Miguel Island, have extensive exposed calcareous accumulations known as caliche. Root-cast or root-sheath caliche was produced after vegetation was buried in sand dunes and then encrusted with calcium carbonate and soil particles during a period of up to 17,000 yr ago (Bremner 1933; Zumberg and Nelson 1958; Johnson 1967; Vedder and Howell 1980). It has become exposed due to wind erosion (Johnson 1980) and is susceptible to damage from both environmental and anthropogenic disturbance. The caliche forests of San Miguel are "among the most interesting and fragile of the geologic features of San Miguel's landscape" (Department of the Interior 1980, 1985). The National Park Service and various public and private institutions have raised concerns about the effects of focused sonic booms from military space vehicle launches from Vandenberg Air Force Base on erosion rates of those caliche forests.

In 1984, we began a long-term photographic study of the San Miguel Island "Caliche Forest" (Fig. 1) to document natural patterns of emergence and erosion of caliche stalks. Using that baseline information, we then determined whether or not focused sonic booms accelerate erosion of stalk caliche.

Methods

We made photographs of caliche from 11 observation points throughout the Caliche Forest in 1984, 1985, 1988, 1989, and 1991. We electronically scanned black-and-white prints (9.0 x 13.0 cm) to form a bit-image database that could then be manipulated to adjust contrast, scale, etc. We then compared the structures of single caliche stalks in consecutive years in order to qualitatively describe changes in emergence of each stalk from the substrate, as soil and sand was eroded from around its base, and changes in the relative size and shape of exposed caliche (Figs. 3–8). We estimated the change in profile area of caliche stalks by measuring the square area of each stalk, comparing it with similar measurements made in subsequent years and calculating differences as annual percent change.