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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.

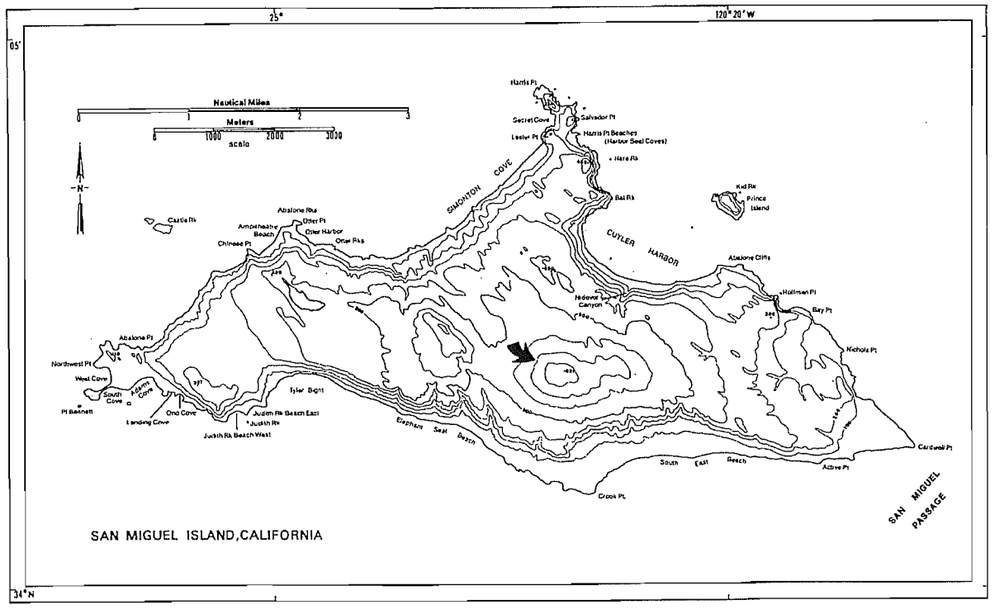

Figure 1. Location of the Caliche Forest on San Miguel Island.

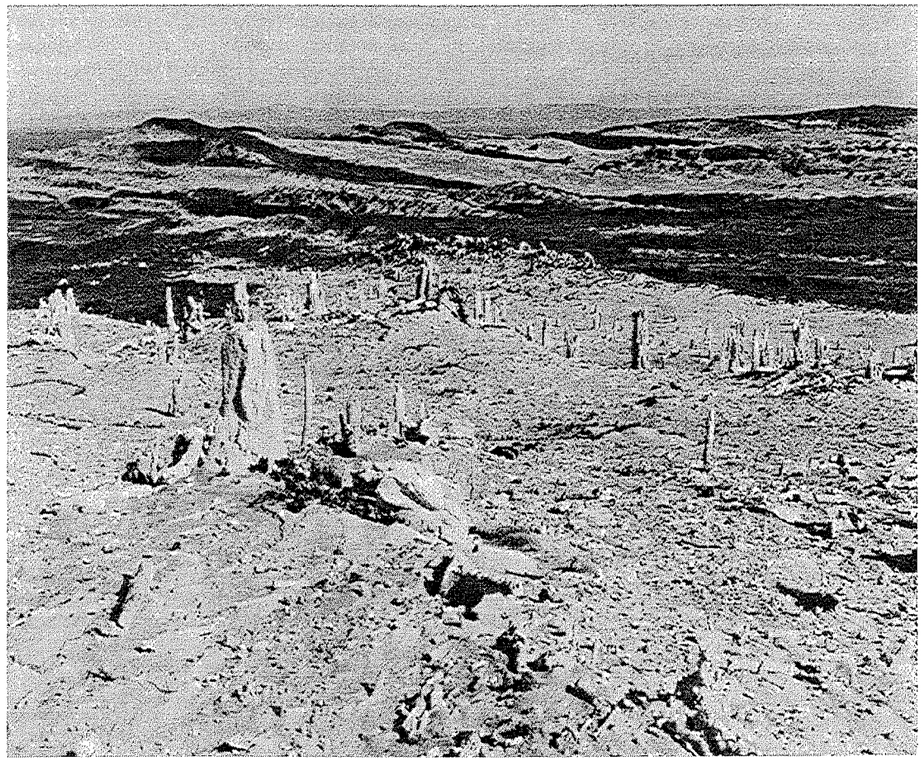

Figure 2. View of the Caliche Forest on San Miguel Island.

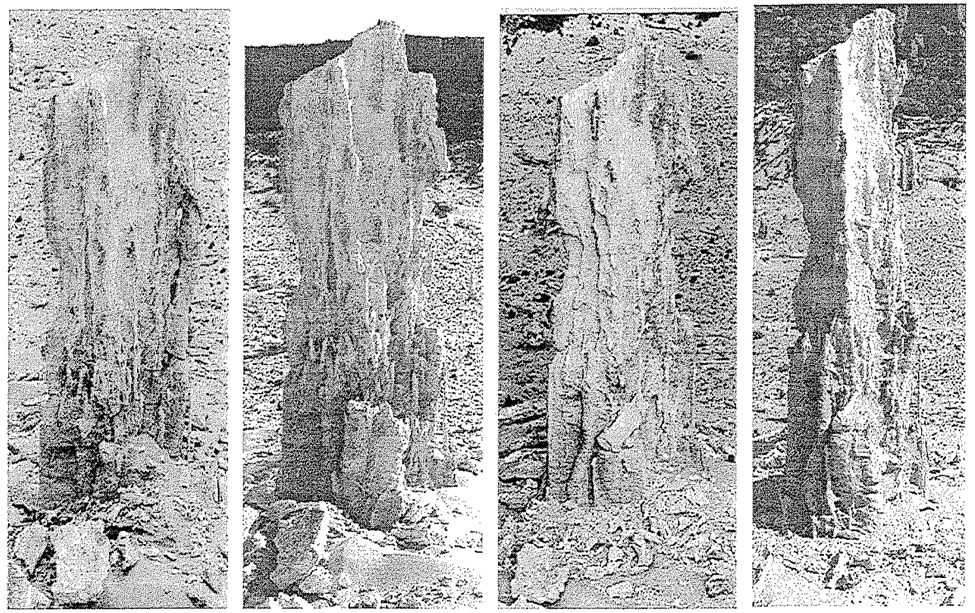

Figure 3. Chronological series of views of caliche Plot A.

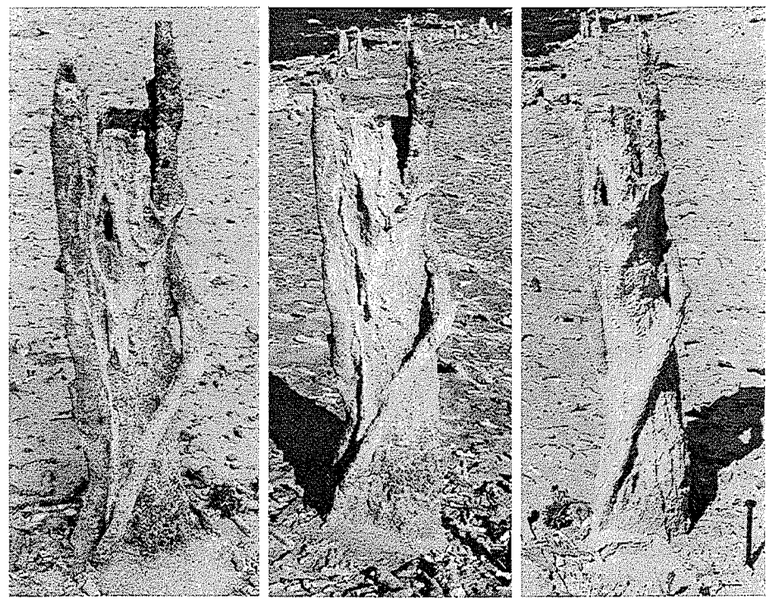

Figure 4. Chronological series of views of caliche Plot B.

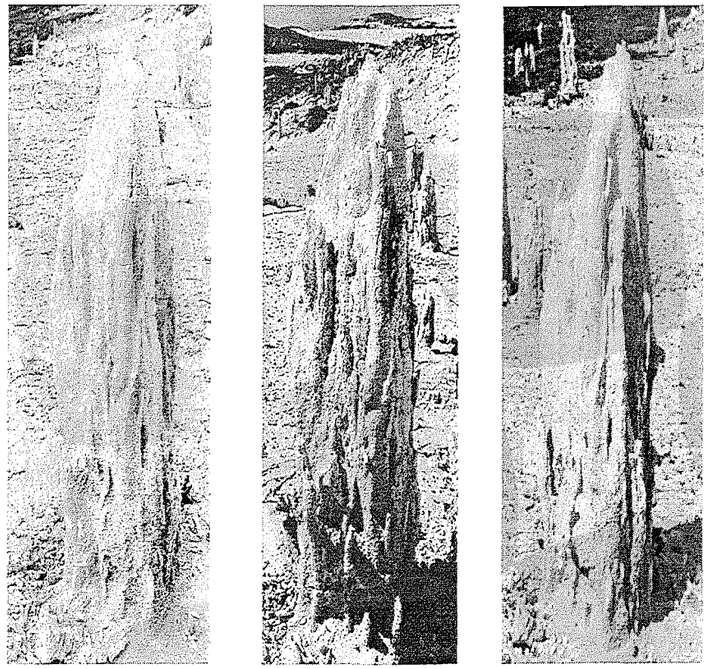

Figure 5. Chronological series of views of caliche Plot C.

Results

Eleven files of sequential photos of caliche plots or individual stalks were obtained during the period of 1984 to 1991. Five panoramic views provide general reference (e.g., Fig. 2), but detection of small changes in caliche stalks from those views is problematic. However, changes were readily distinguishable in 6 plots of individual caliche stalks (Figs. 3–8).

There was little to moderate change in caliche in plots A and B as small pieces, amounting to less than 10%, eroded within 1 to 4 yr (Figs. 3 and 4), and there was little if any change in caliche in plots C and D (Figs. 5 and 6) from 1984 through 1991. There was substantial erosion to caliche in Plots E and F; around 30–75% of the stalks had eroded within 1 to 2 yr (Figs. 7 and 8).

The plots showing the greatest change were those that were tall (Plots E and F) or had thin appendages (Plot B; Table 1). Those that showed little or no change were short and squat and lacked detailed appendages (Plots A and C; Table 1).

In addition to changes in the individual caliche stalks, changes in the ground level and plant cover in those areas were obvious. Plots A and B showed changes due to erosion as more of the stalk was exposed as the ground level dropped. Sand drifts or small sand dunes observed in some years were not observed in others as the sand shifted, caused by variation in wind or rain patterns among years.

Discussion

Erosion of caliche stalks can be substantial within 1 yr, depending on their size, shape, and profile. We assume that wind and, to a lesser extent, rain are the major agents of erosion that cause sections of caliche to break away from stalks.

Animal movements can also substantially alter stalk and surface-deposit caliche structures, particularly at areas where seals and sea lions haul out to breed or rest. For example, erosion of a massive caliche deposit at the west end of San Miguel Island (Point Bennett) was accelerated by the movements of pinnipeds; that structure has virtually disappeared during the past decade.

Earthquakes also may affect stalks weakened from erosion, although we have no direct observations of this. Due to limited access to the island, and the controlled visitation to the Caliche Forest, destruction of caliche structures by humans is unlikely to have influenced the appearance of the Caliche Forest during the past decade.

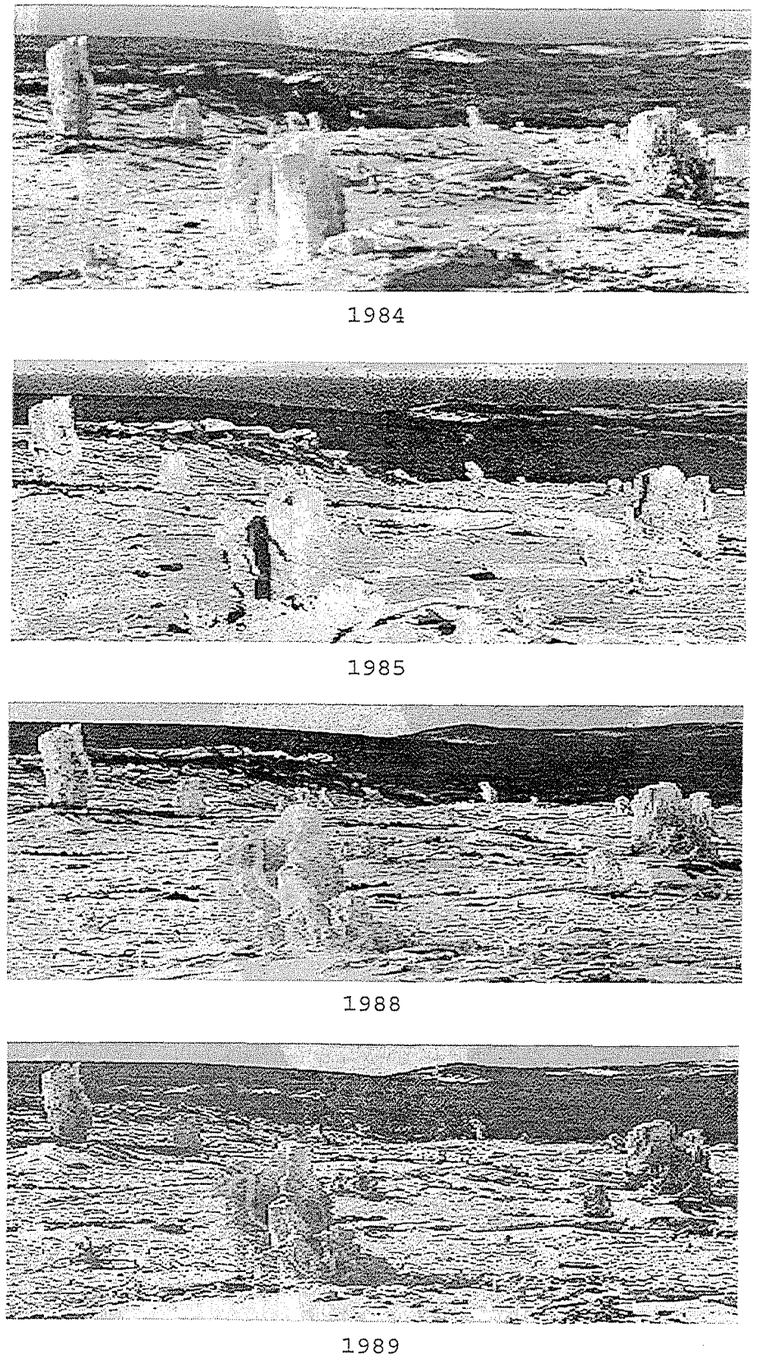

Figure 6. Chronological series of views of caliche Plot D.

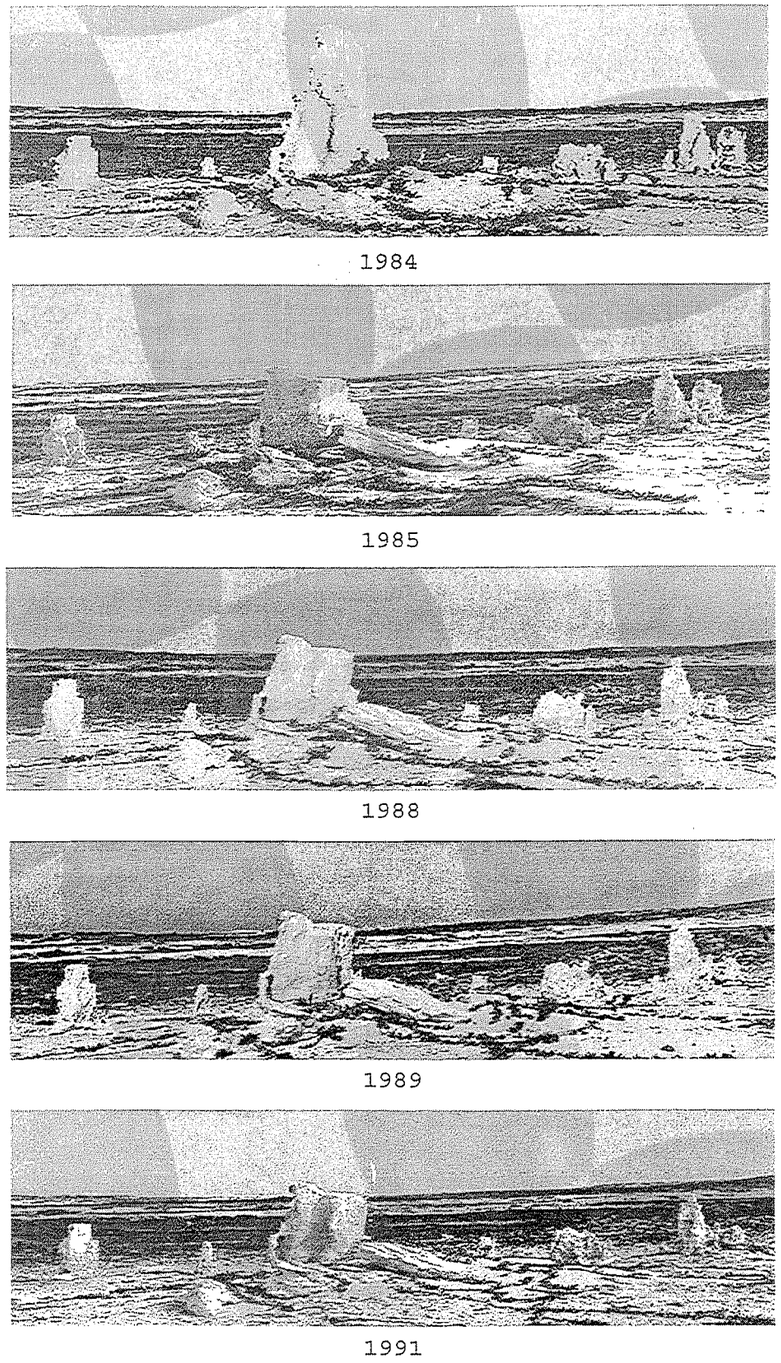

Figure 7. Chronological series of views of caliche Plot E.

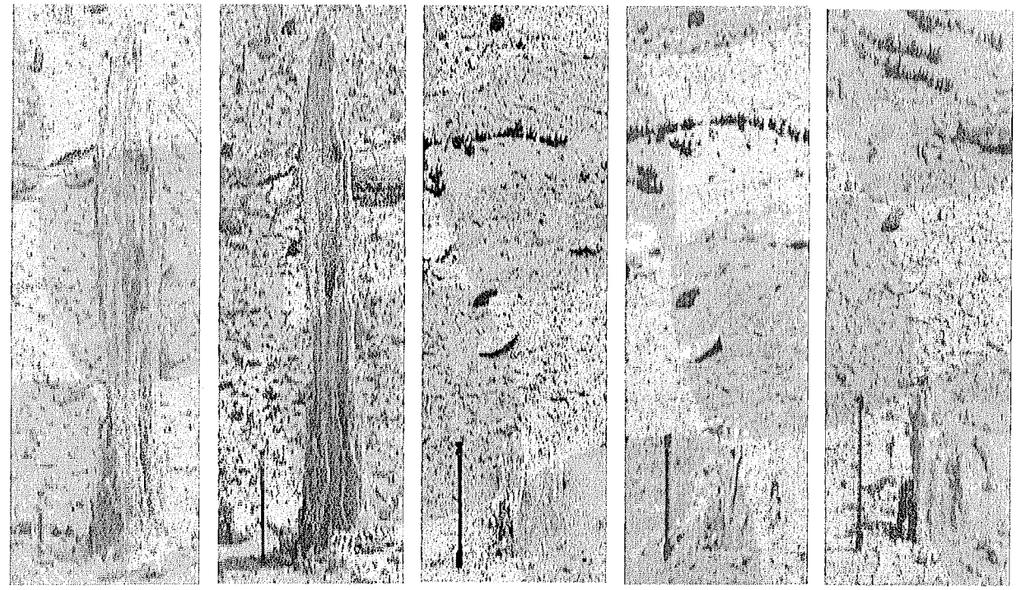

Figure 8. Chronological series of views of caliche Plot F.

Table 1. Percent change in individual caliche stalks.

Caliche plot	Percent change from previous years				
	1984–1985	1985–1988	1988–1989	1989–1991	1984–1991
A	+ 18	– 8	—	+ 15	+ 25
B	+ 10	—	—	– 8	+ 2
C	—	—	0	0	0
D	0	0	0	0	0
E	– 28	0	0	0	– 28
F	+ 8	– 78	– 15	– 5	– 72

High winds are common on San Miguel Island and can transport large amounts of sand to, or away from, the bases of caliche stalks; winds can also cause direct erosion of caliche features through abrasive action (Johnson 1980). Drought conditions prevailed at San Miguel Island during most of the past decade, so the effect of water erosion may have been minimal. Humidity is normally high, however, particularly during summer months when fog is common but the effects of such humidity in softening structures and influencing erosion rate is unknown. In past years, low-intensity sonic booms have occurred frequently (Bowles and Stewart 1980), but we know of no direct observations of caliche stalk response to those mild to moderate booms. Environmental factors have almost

certainly been the dominant force, though, in exposing, covering, eroding, or breaking caliche stalks in the Caliche Forest.

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