BA7

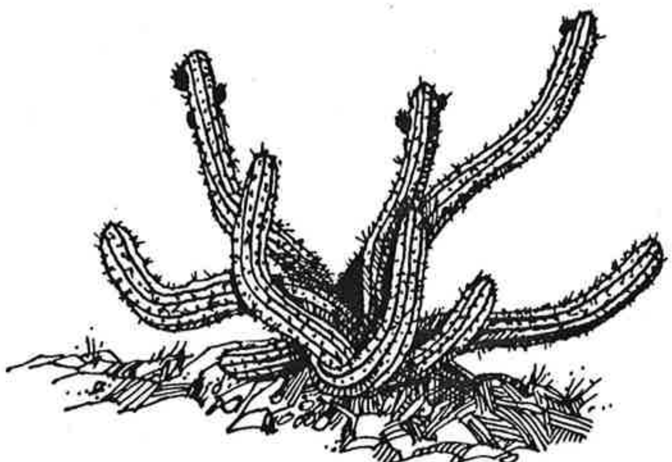
1988

BAJA FIELD TRIP GUIDE

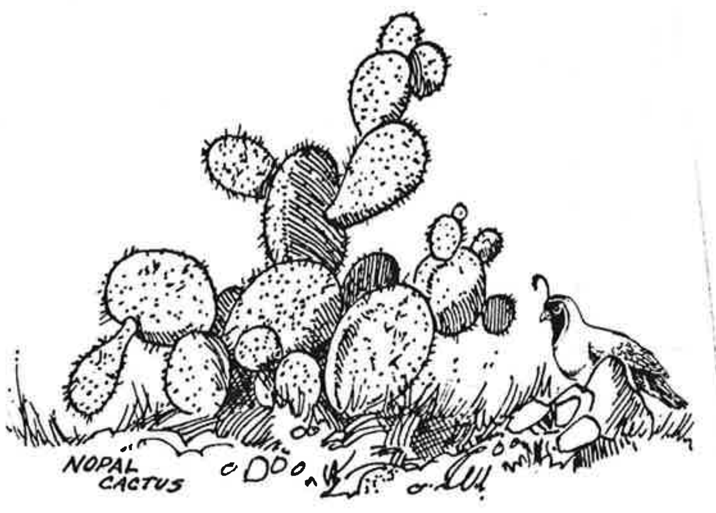
M. LENEMAN

BLUE PALM

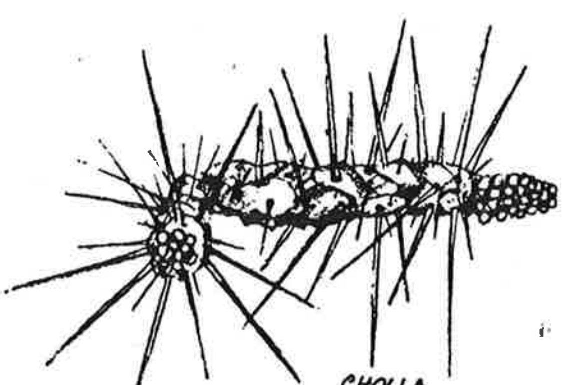
TREE YUCCA



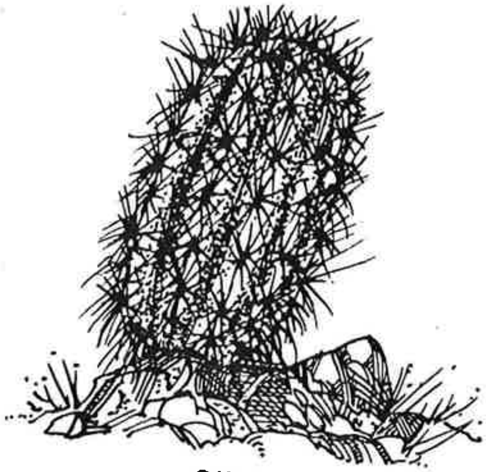
PITAHAYA



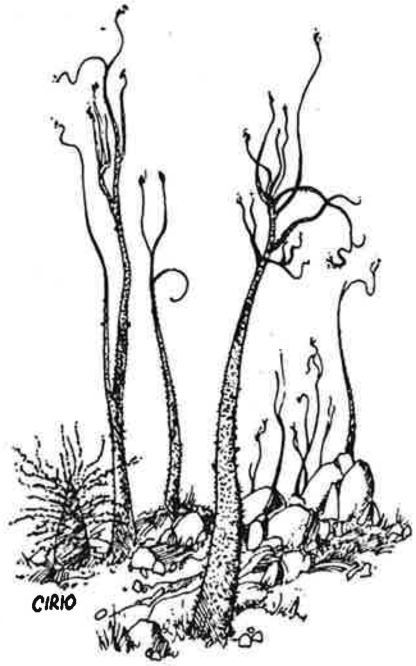
NOPAL CACTUS

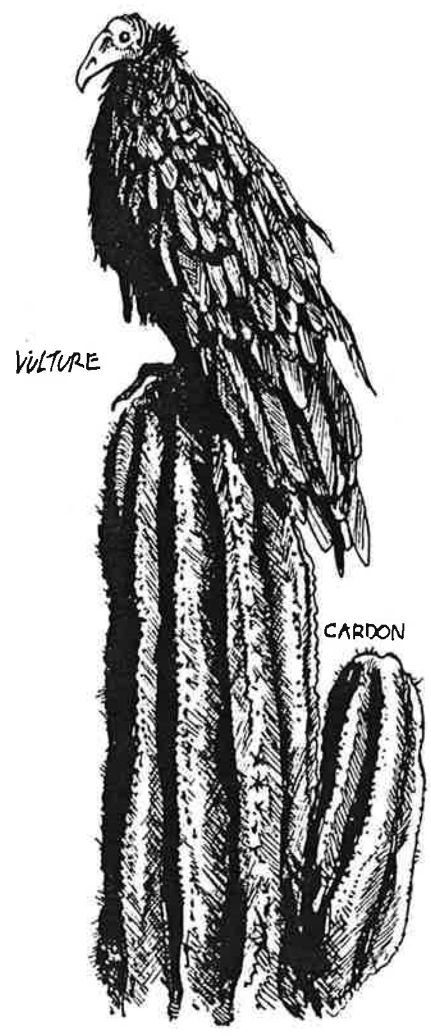


CHOLLA CACTUS



BARREL CACTUS OR BIZNAGA





OUTLINE OF GEOLOGIC HISTORY

The rocks of Baja California contain the record of two geologic revolutions: we call the first the "mid-Mesozoic event" and the second the "mid-Cenozoic event." The mid-Mesozoic event occurred from Jurassic through middle Cretaceous time and is documented by volcanic strata of the island-arc type, regional metamorphism, and the emplacement of pervasive granitic rocks. It involved profound structural deformation, uplift, and erosion and probably resulted in fundamental geographic changes. The mid-Cenozoic event involved the accumulation of a wide variety of volcanic rocks, minor(?) metamorphism and granitic emplacement, and the creation of the Gulf of California, a mobile tectonic belt. This event, initiated at or before the beginning of the Miocene Epoch, is still going on.

These two events divide the history of Baja California into significant intervals. Everything that occurred before the culminating granitic emplacements of middle Cretaceous time is referred to as "prebatholithic"; everything thereafter, as "postbatholithic." Postbatholithic history is divided into events that occurred before the formation of the Gulf of California province (approximately 30 m.y. ago) and those that occurred afterward.

Prebatholithic Terrane

The preintrusion rock patterns and geologic history of Baja California are poorly known because the prebatholithic rocks have been metamorphosed and intruded by an extensive belt of batholiths. Furthermore, many areas critical to the study are submerged beneath the Pacific Ocean and the Gulf of California.

We divide prebatholithic rocks of the state of Baja California into four belts, three on the peninsula (Fig. 4) and one to the west on the continental borderland. Localities cited in this chapter are shown in Figure 4.

The rocks of the westernmost belt are exposed only on some of the offshore islands, the Vizcaíno Peninsula to the south, and the Palos Verdes Peninsula of Los Angeles County. These rocks are similar to those of the Franciscan assemblage (Bailey and others, 1964) of northern and central California, U.S.A. Along the western shore of Baja California is a belt consisting of volcanic and volcaniclastic rocks. In the central part of the peninsula is a belt of metamorphosed shale and sandstone. On the eastern side is a belt that contains a great variety of metasedimentary rocks, including those derived from carbonate rock, chert, wacke, pebbly mudstone, arkose, quartz sandstone, and shale. These four belts are delineated only by rock type. We do not imply a sequential stratigraphic relation between rocks of these associations.

Mesozoic Thermal Event

It has long been recognized that a belt of "Mesozoic" batholiths extends from the Aleutian Peninsula more than 6,000 km to Central America (Daley, 1933). Prominent in this chain are the Coast Range batholith of southeastern Alaska and British Columbia, the Idaho batholith, the Sierra Nevada batholith, and the Peninsular Ranges batholith of southern California and Baja California. This belt is located in a somewhat broader belt of metamorphosed and folded rocks.

Metamorphism and batholithic emplacement are commonly considered to be of Mesozoic age. Some plutons, however, are at least as old as late Paleozoic, some are as young as Miocene, and the region is still thermally alive in many places.

Mid-Cenozoic Volcanism

During late Oligocene or early Miocene time, a new tectonic regime began. This was not a continuation or rejuvenation of the Mesozoic mountain building that encircled the Pacific Ocean but rather a dilational event extending from the Pacific Ocean to the Colorado Plateau. Block after block of the once stable granitic crust broke into elongate splinters that sank, tilted, and in some places squeezed against one another. Over this terrain of broken and tilted crust poured rhyolite, andesite, dacite, and basalt. Plutonic intrusion and metamorphism occurred locally. Today, the area affected by this event is called the Basin and Range province (Fig. 1). The Gulf of California and the eastern third of the state of Baja California are included in this province. During the Miocene Epoch, the gulf extended into areas where there had been no sea for more than 100 m.y. Ultimately, gulf waters lapped against the foothills of the Transverse Ranges and the eastern valleys of the Mojave Desert in California, U.S.A., and extended into Arizona and Sonora. Although late Pliocene and Pleistocene strata lie flat in many areas, suggesting recent stability, the gulf province is seismically and thermally active, implying that plutonic and metamorphic activity continues at depth.

Late Cretaceous and Early Tertiary Time

Typical postorogenic activity occurred during Late Cretaceous through Paleocene and Eocene time. Following the emplacement of batholithic granitic rocks, probably completed about 90 m.y. ago, the Peninsular Ranges underwent uplift, cooling, and erosion. The principal areas of Mesozoic plutonic activity have remained emergent to this day.

A tremendous volume of eroded debris was transported westward to the Pacific Ocean and was deposited near the present shoreline. The outcrops of Upper Cretaceous and lower Tertiary rocks that resulted are shown in Figure 20 as well as the locations cited in Chapter 4. The Upper Cretaceous deposits were derived entirely from the granitic and metavolcanic rocks of the western and central parts of the peninsula. The resulting conglomeratic and arkosic debris built molasse-type deltas out to the edge of the continental slope.

By Eocene time, the Mesozoic mountains were reduced to isolated hills separated by alluviated pediplains across which flowed rivers that rose in the interior of the continent. Many of the clasts in the Eocene and Paleocene deposits were derived from rocks east of the central portion of the peninsula and were transported across the newly formed pediplains toward the Pacific Ocean.

Following Eocene time, the crustal areas now occupied by the Basin and Range province, including the Gulf of California, began to subside relative to the crustal area now occupied by the peninsula of Baja California. The rivers from the interior drained into interior basins and the proto-Gulf of California.

Flooding of the Gulf of California and the Continental Borderland

PLIOCENE EPOCH ON THE PACIFIC COAST

By Pliocene time, the Baja California Peninsula had assumed much of its present geographic form. The Gulf of California extended as far north as the Transverse Ranges in California, U.S.A., and the Pacific coastline stood close to its modern position. To the west, the continental borderland had subsided into a series of linear troughs and ridges (Moore, 1969, p. 44) with a few islands remaining exposed. The peninsula extended south at least to the La Paz embayment.

During early Miocene time, the sediment derived from the peninsula was transported westward past the present shoreline and deposited on a broad, open continental terrace that is now the continental borderland (Moore, 1969). The mid-Miocene orogeny folded and faulted this area, and Pliocene faulting formed new basins.

Minch (1967) extended the name San Diego Formation to the Playas de Tijuana-Rosarito Beach area (locs. 1 and 2). Formación Salada was designated as a group by Durham (1950) and in Mexican publications has come to mean all marine Pliocene strata of the peninsula. Formación Cantil Costero (Santillán and Barrera, 1930) was designated as middle and upper Pliocene, whereas the San Diego Formation was interpreted as upper Pliocene (Valentine and Rowland, 1969).

The marine Pliocene deposits of southern California and northern Baja California are littoral sandstone and conglomerate derived from the basement and older sedimentary strata immediately to the east. The fauna from these deposits was described and interpreted by Hertlein and Grant (1939), Gunther (App. 2), Minch (1967), Andersen (App. 2), and Valentine and Rowland (1969). In the territory of Baja California, the fauna was described by Darton (1921, p. 747), Heim (1922, p. 544-546), Hertlein (1925), Beal (1948, p. 80-81), and Mina (1957, p. 179, 207-208).

Although the Pliocene beds of western Baja California are nearly horizontal, their elevations vary. The highest Pliocene shoreline in the area southeast of Playas de Tijuana is about 200 m above sea level (loc. 3). From Rosarito Beach (loc. 2) to Punta Banda (loc. 4), the highest Pliocene terrace is apparently below current sea level. From Punta Banda south to Socorro (loc. 8), extensive Pliocene deposits occur at elevations of 100 to 200 m. From Socorro southward, the Pliocene terrace climbs to elevations of around 300 m northeast of El Rosario (loc. 10). Pliocene strata are 500 m above sea level at Mesa San Carlos (loc. 11), 100 to 200 m along the coast south of Punta Canoas (loc. 12), and at less than 50 m above sea level farther south (locs. 18 and 21). Orme (1971) reported that the highest terrace is at 345 m at Punta Banda, at 357 m at El Rosario, and below sea level at Camalú about halfway between Punta Banda and El Rosario. On paleontologic evidence, the maximum terrace elevations to which Orme referred are of Pliocene age (Acosta, App. 1).

Pleistocene and Holocene Epochs

PACIFIC COASTAL TERRACES

Just north of the international border, in the San Diego area, a number of Pleistocene terraces have been recognized (Hertlein and Grant, 1944), and several formation names have been applied to the deposits capping them. Of these, the two most distinctive units are the red ferruginous conglomerate and sandstone that cap the mesa at elevations of 100 and 150 m and the very fossiliferous sandstone or coquina that is found near sea level. The mesa-capping rocks are referred to as the Lindavista terrace deposit (M. A. Hanna, 1926); the sea-level deposits are named the Bay Point Formation by Hertlein and Grant (1939) for the occurrence on the north shore of Mission Bay. South of the border, formal formation names have not been devised, but a similar red layer caps the hills south of Tijuana and on South Island of Islas los Coronados. A fossiliferous terrace deposit a few meters above sea level extends almost continuously from Playas de Tijuana to La Misión (locs. 1 to 2 in Fig. 34, which shows locations for Chap. 7).

Schroeder (App. 1) described the Pleistocene terrace deposits just south of Ensenada (loc. 3), and Acosta (1970) described those extending from Punta Banda (loc. 4) to Punta China (loc. 5). Emerson (1956, 1960) investigated the deposits from north of Punta Santo Tomás (loc. 6) to Punta San José (loc. 7). Emerson and Acosta applied the name Punta China terrace to the prominent bench standing between 5 and 16 m above sea level. Lindgren (1888), Allen and others (1961), and Acosta (App. 1) recognized as many as 12 higher terraces in the Punta Banda area (loc. 4), north of the Agua Blanca fault (Pl. 3); the highest terrace was almost 350 m above sea level. Acosta also reported that the highest terrace (250 m) south of the Agua Blanca fault was dated as Pliocene on the basis of fossils collected by John Minch (1966, written commun.).

Emerson (1960) described the terrace at Punta Cabra (loc. 8). The terrace at San Quintín (loc. 16) was studied by Orcutt (1921), Jordan (1926), Woodford (1928), and Gorsline and Stewart (1962). From San Quintín to Punta Canoas (loc. 24), our field parties mapped a succession of four terraces. The highest of these contains Pliocene fossils; the lowest is the prominent Pleistocene terrace referred to above (terrace T1 in Fig. 35).

It may be significant that, in those areas where the coastline projects westward into the Pacific, the Pliocene and older Pleistocene terraces are tilted seaward and attain greater elevations, whereas in all areas the youngest terrace is essentially horizontal. This strongly suggests that the elevated areas were produced by post-T2, pre-T1 deformation that produced broad buckles on axes subnormal to the coast.

On terrace T4 (Fig. 35), fossiliferous Pliocene strata are overlain by basalt. Terraces T2 and T3 are capped by a thin cobble layer that includes basalt. Farther north, supposedly correlative surfaces are of marine origin. Terrace T1 forms a prominent, nearly horizontal bench 10 to 20 m above sea level. The marine deposits of T1 fill irregularities on a channeled surface, suggesting that sea level fell below its present elevation between formation of T2 and T1. According to Emerson and Addicott (1958), the low terraces (loc. 18) were deposited under essentially the same conditions that exist along this coast today.

South from Punta Canoas, fossiliferous Pleistocene beds occur just above sea level. In many places, they are covered by fluvial gravel or eolian sand. Emerson and Hertlein (1960) studied a late Pleistocene marine fauna in a terrace about 7 m above sea level at Punta Rosarito (loc. 28; lat 28°40′ N.).

Fife (App. 1) described the Bahía Santa Rosalía localities (lat 28°30′ to 29° N.) as follows:

> Near the coast there are several terraces. The most prominent are at the 15-20, 60, and 140-foot elevations. The fifteen to twenty-foot terrace affects only sedimentary rocks; it consists of a 1,000-foot wide bench south of El Muertito; and can readily be recognized [to the] south in the Puerto Santo Domingo Quadrangle. . . . The higher terraces have been cut up to several hundred feet into the granitic rocks north of El Tomatal. North and south of the mouth of Arroyo Rosarito the sixty-foot and the 140-foot terraces merge, obscuring the sixty-foot terrace. The sixty-foot terrace follows the present coastline around the mouth of the arroyo, while the 140-foot terrace curves upstream for a few miles.
>
> East of Santa Rosalillita the higher surface rises as a gentle plain for about four miles, reaching a maximum elevation of about 200 feet. Beyond this elevation the terrace or terraces have been so modified by erosion that one terrace grades imperceptibly into another. This is about 100-200 feet lower than the highest surface preserved by the Miocene volcanic rocks.

South from lat 28°30′ N., the coastal plain becomes broad and submergent. Beneath the sand dunes, the entire coastal terrace is capped by hard calichified

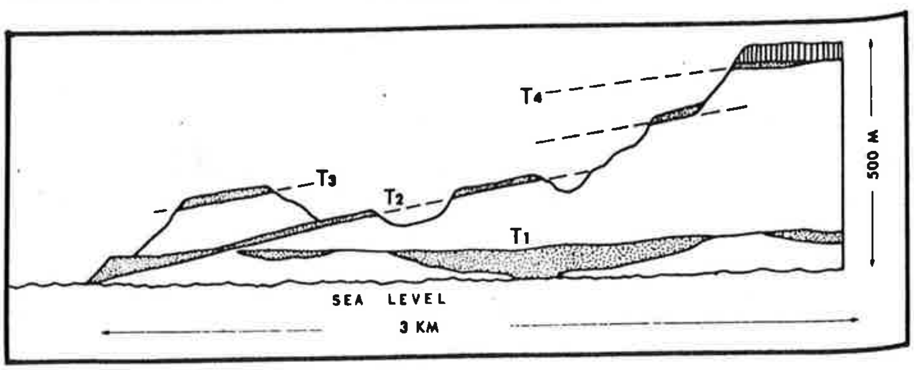


Figure 35. Diagrammatic sketch of terraces T1 through T4 west of Mesa San Carlos, Pacific coast of Baja California, at lat 29°30′ N.

white sandstone as much as 3 m thick. This overlies reddish-brown, moderately friable sandstone and argillaceous siltstone that continues downward at least to the bottom of the deepest arroyos.

After GSA
Memoir 140
Gastil, Phillips & Allison
1975

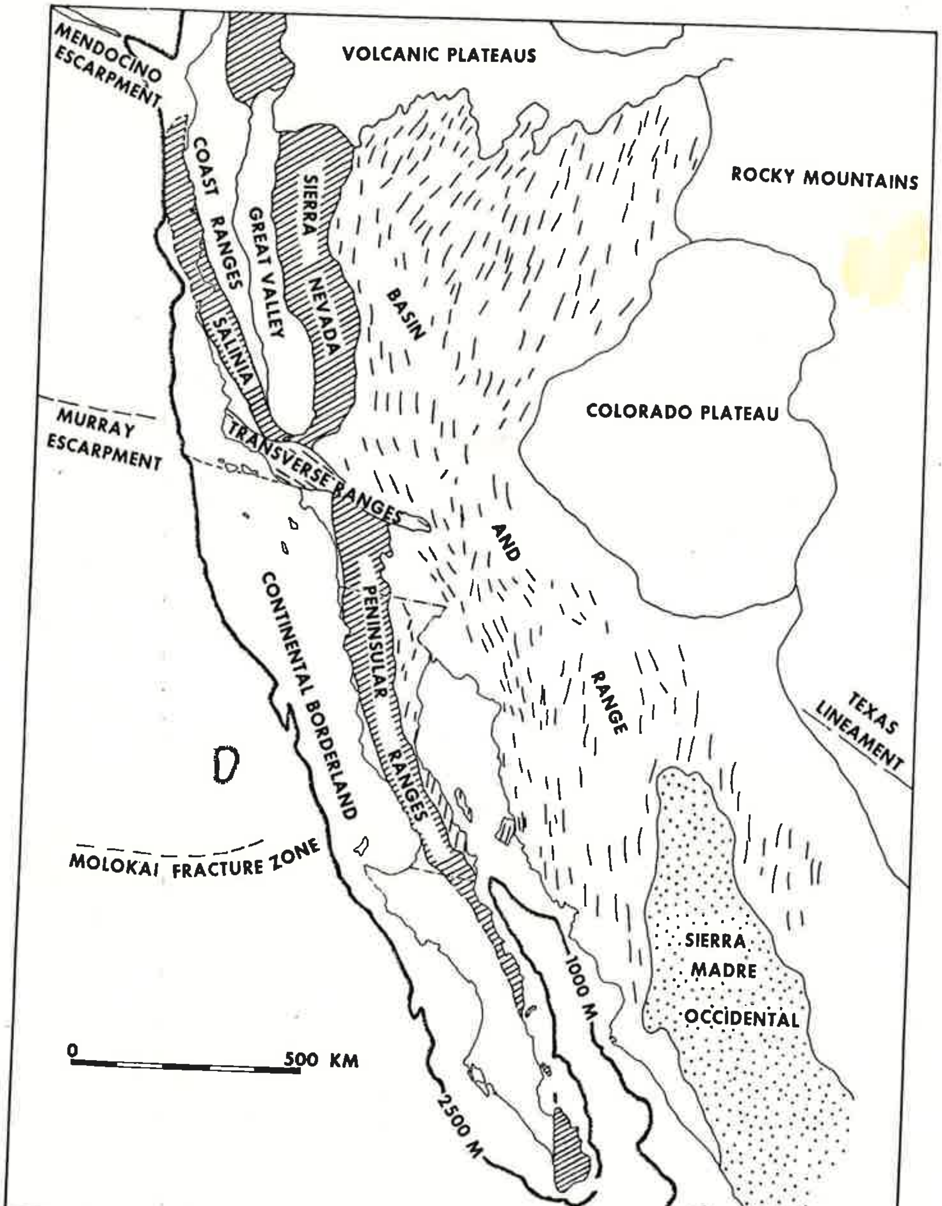


Figure 1. Regional setting of the state of Baja California. The continental edge is marked by the 1,000-m isobath in the Gulf of California and the 2,500-m isobath in the Pacific Ocean.

in Baja California (Aerospace Center of Defense Mapping Agency, 1969). Unfortunately, all three of these groups of maps are very misleading in respect to roads, place names, and (to a lesser extent) drainages. The 1:1,000,000 road map by Gerhard and Gulick (1970) is accurate. The road map and guidebooks for Baja California (Automobile Club of Southern California, 2601 South Figueroa Street, Los Angeles, 1973) are up-to-date in most areas. Areas north of lat 30° N. are

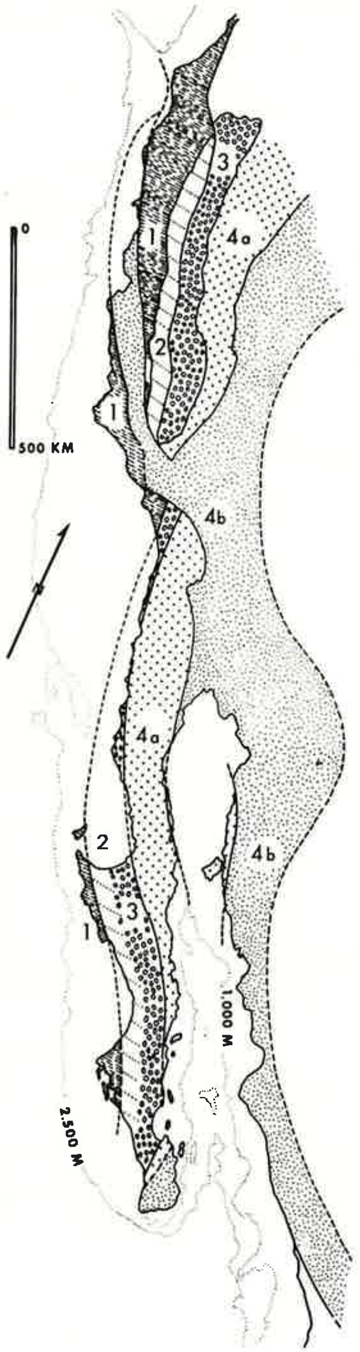


Figure 63. Structural framework of California, U.S.A., and Baja California. 1, Franciscan assemblage; 2, thick fill of the older Great Valley sequence; 3, thick fill of younger Great Valley sequence; 4a, Mesozoic-Paleozoic volcanic-volcaniclastic strata intruded by potassium-poor plutons; 4b, Paleozoic carbonate and quartzite strata intruded by relatively potassium-rich plutons.

1

Regional Tec

MESOZO

We assume that the great cordilleran ba
at the roots of dacite-andesite arcs analo
Chile (Hamilton, 1969a). If we examine s
belt of ocean-floor and trench deposits (oph
minerals such as glaucophane), (2) a belt o
(volcaniclastic rocks, graywacke, argillit
metamorphic and plutonic provenance, a
by the arc of andesitic volcanos, pluto
composition. Moore (1959) and Dickinso
this belt of plutons becomes progressively
of the arc.

In northern California, this first-order
by the following belts: (1) Franciscan and
part of the Great Valley sequence, (3) t
(4) the Sierra Nevada batholith. The Sierra
into (4a) a subbelt in which the country ro
volcaniclastic deposits that range from dee
by predominantly potassium-poor pluton
and (4b) a subbelt in which the country ro
mentary carbonate rock and quartzite that
plutons of Late Cretaceous age. Similar
western Alaska and in other eroded arc s

South of the Transverse Ranges, the
broad submerged area along the continenta
however, in the Channel Islands, Islas Cedr
and the Bahía Magdalena area. For the
western belt composed of pillow basalt
and serpentinite; (2) a belt of Jurassic and m
to the older Great Valley sequence and
(Kilmer, 1969) and on the Vizcaíno Pen

Punta Banda Structure

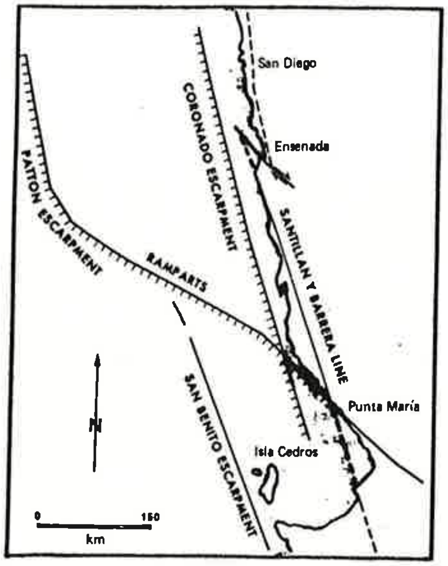


Figure 56. Major structural elements of the continental borderland west of southern California and the state of Baja California.

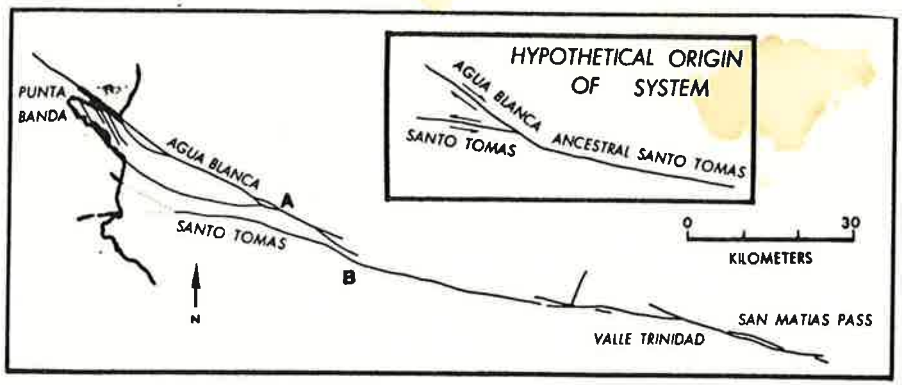


Figure 58. Agua Blanca-Santo Tomás fault system: A, junction of Valle Santo Tomás and the Agua Blanca fault; B, a point near Rancho Zacatán where the Agua Blanca fault bends

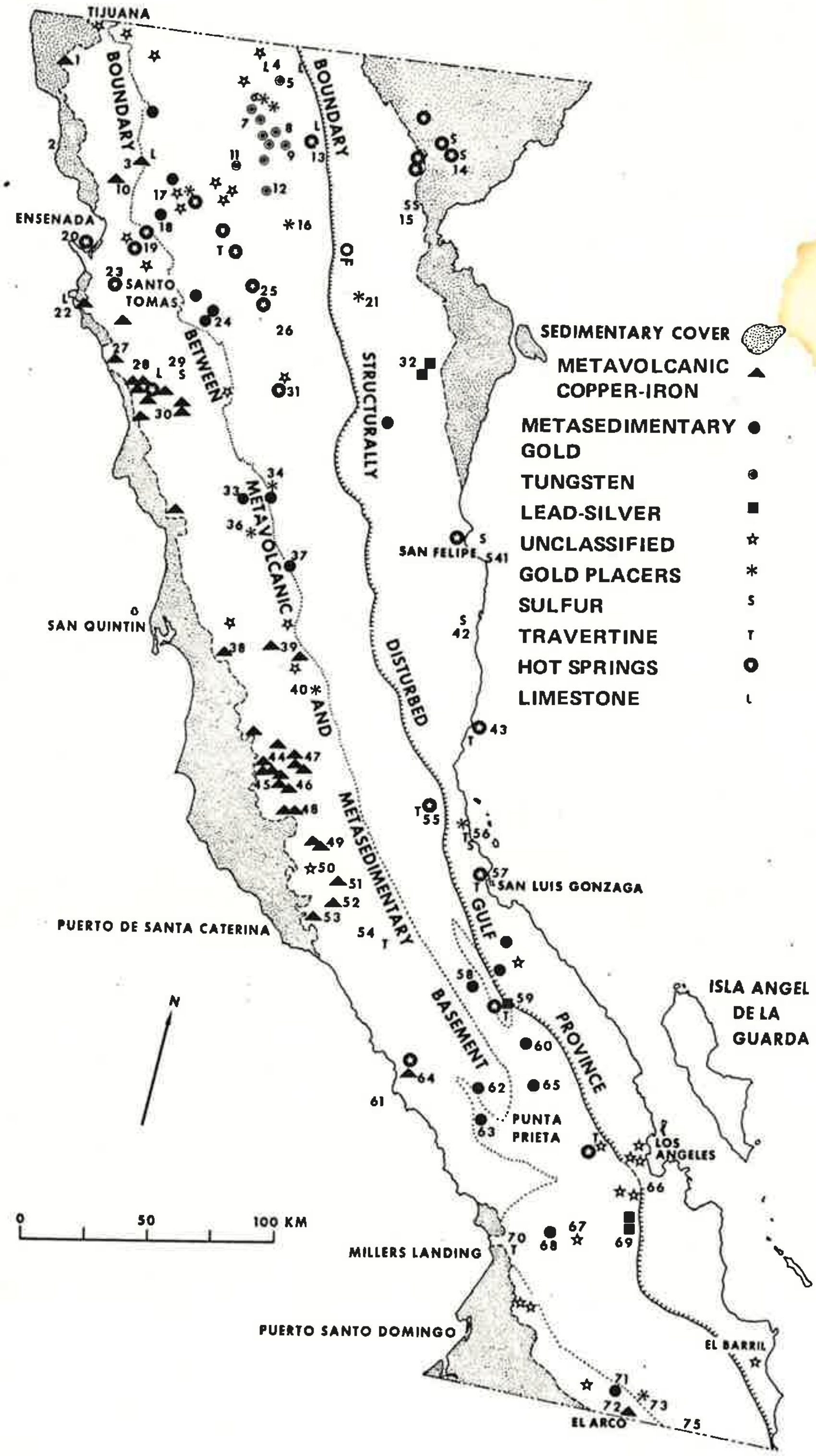


Figure 66. Mineral deposits in the state of Baja California. Numbers 1 through 75 correspond to localities cited in the text.

1

Economi

HISTORY OF MINERAL EXPL

During the mission period, from first ex
and diaries indicate that mining, except
silver and gold mines in the mountains
mineral discoveries (Meigs, 1935; Aschn

There are, however, several reasons t
did take place during this interval. For
in a footnote (1959, p. 25):

When, in 1774, an Indian found a good-size
de los Angeles, the missionary promptly re
that the bar had been lost by someone en
forfeit to the crown. The Dominicans accept
to have been glad to lose the gold rather tha
mine.

It is difficult to visualize how a mining
lose a good-sized ingot could have gone

In 1792 José Longinos Martínez mad
the express purpose of recording the p
phenomena (Longinos Martínez, 1792).
by training, he was a keen observer of
He wrote the following account of
mentioned in Chap. 12 are shown in Fig

In this canyon there are veins of silver and
because of the desert nature of the place
district there are hills which can be seen f
of *copperas* [p. 29].

The deposits that have since been mi
by simply riding through the canyon.
He described the deposits on the weste