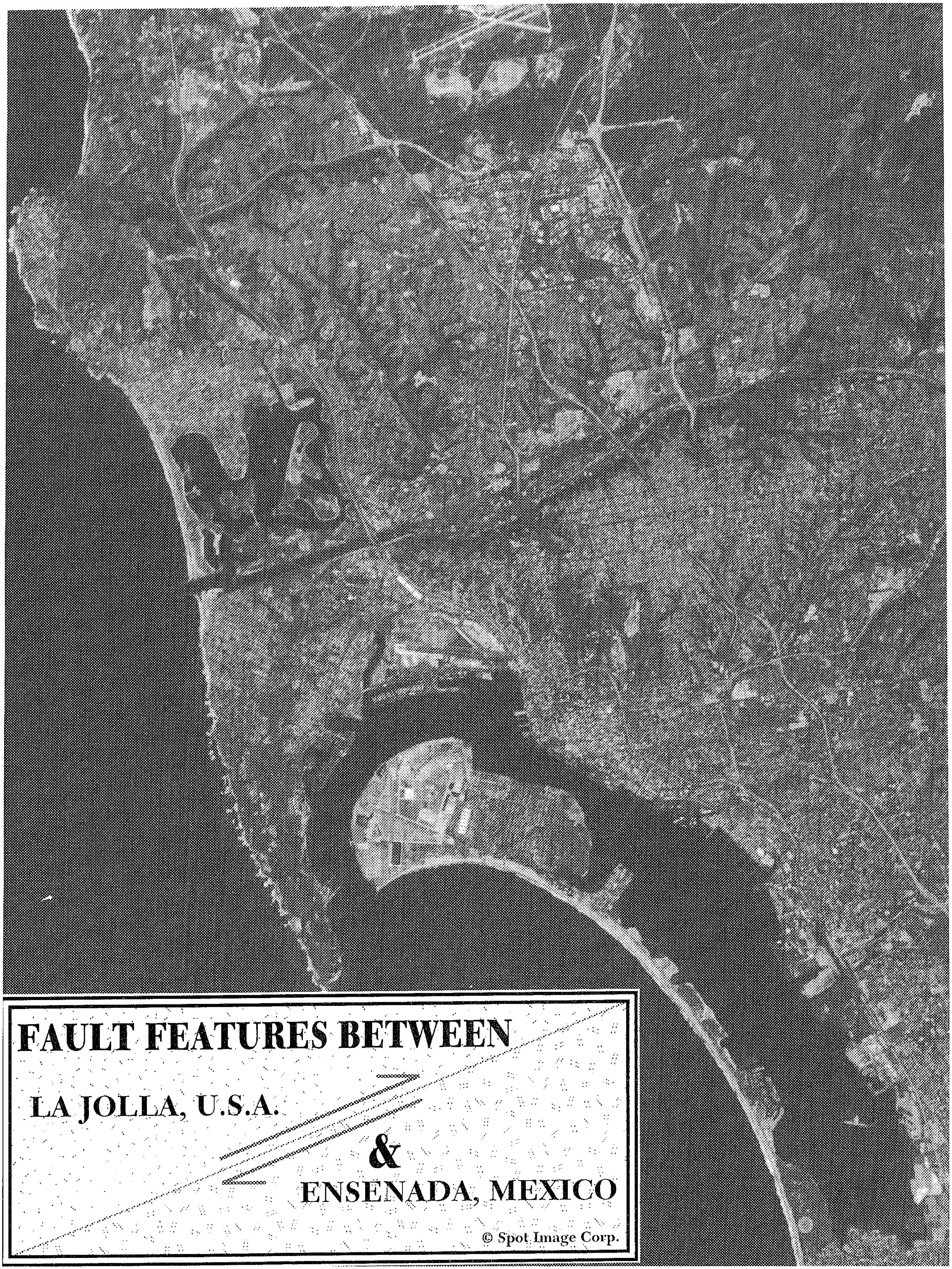


FAULT FEATURES BETWEEN

LA JOLLA, U.S.A.

&

ENSENADA, MEXICO

SAN DIEGO ASSOCIATION OF GEOLOGISTS

Field Trip Road Log **October 21 & 22, 1989**

Fault Features Between La Jolla, U.S.A. and Ensenada, Mexico

Field Trip Leaders

Field Trip Chairperson
Diane Murbach
Geopacifica

Mark R. Legg
Acta, Inc.

Monte Marshall
San Diego State University

Perry Crampton
Scripps Institute of Oceanography

Tom Kuper
Geocon, Inc.

James R. Ashby
Soil & Testing Engineers

John A. Minch
Saddleback College

1989 S.D.A.G. Executive Committee

Introduction

This year the San Diego Association of Geologists 1989 Annual Field Trip will travel between La Jolla, U.S.A. and Ensenada, Mexico exploring fault and geologic features. This road log has been prepared subsequent to the workshop on the Rose Canyon fault system for seismic risk in the San Diego region. This workshop was held June 29-30, 1989 in conjunction with the Southern California Earthquake Preparedness Project (SCEPP) and the U.S.G.S. This road log is a part of the 1989 publication to be entitled, "Proceedings of the Seismic Risk in the San Diego Region Workshop on the Rose Canyon Fault Zone".

A bi-national earthquake preparedness project is looking at the problems that could occur in the border area should a damaging earthquake strike and actually damage both the San Diego and adjacent Tijuana metropolitan area. As a geologic community, we must continue with additional investigations and analyses directed towards the potential hazard of surface fault rupture. Investigations should be directed towards locating existing faults and attempting to evaluate the recency and recurrence of faulting, and establishing the amount and style of slip. Models used to assign seismic risk need to be evaluated and tested against real field data.

Follow our road log for a general overview of old and new geologic topics along our local faults.

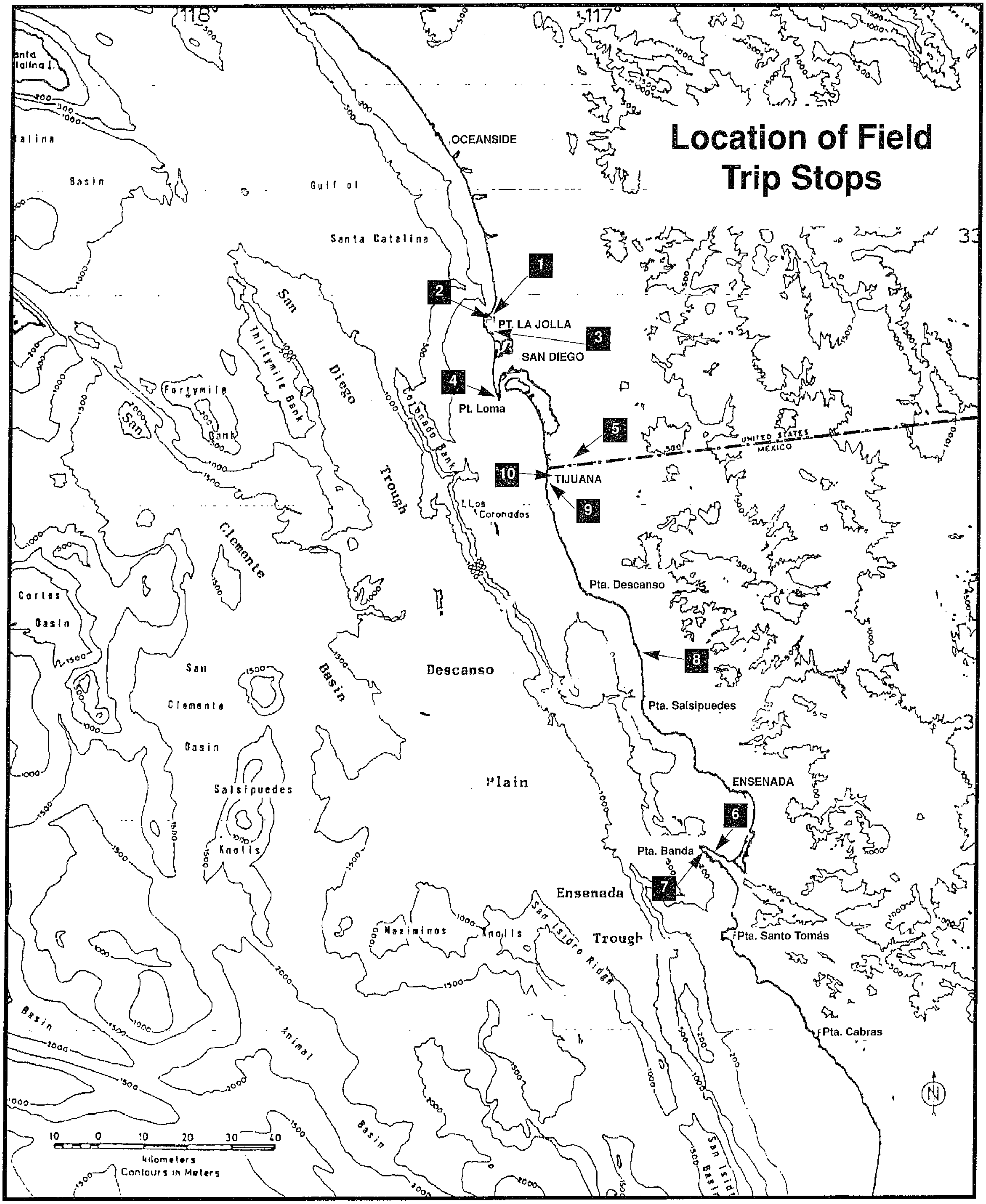
Hasta Mañana

Diane Murbach
Field Trip Chairperson

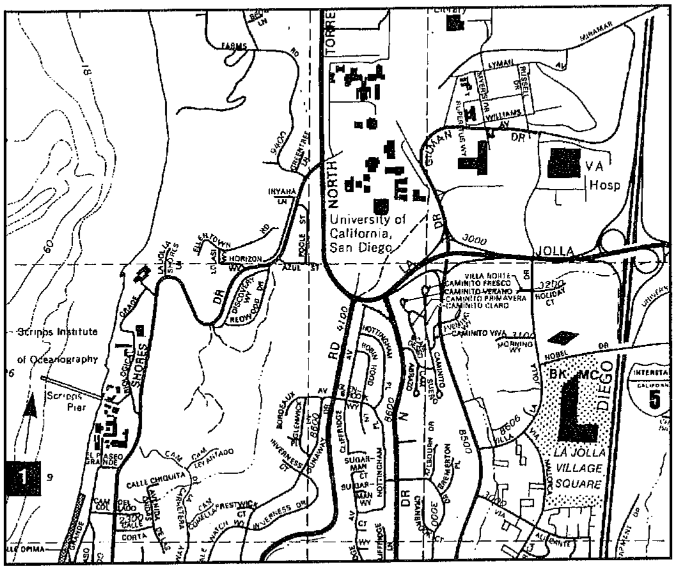
October 1989

Acknowledgments

The San Diego Association of Geologists is grateful to the many individuals and companies who contributed their time and financial support in order to make this year's field trip and accompanying guidebook possible. We wish to thank James F. Knowlton with Geopacifica, Shura Chenkin and Raquel Aceves with Graphic Advantage in Encinitas, CA for their support, design and layout. The authors and field trip leaders deserve our thanks for their time and energy spent in preparing the manuscripts and field trip stops.



Location of Field Trip Stops
OCEANSIDE
PT. LA JOLLA
SAN DIEGO
Pt. Loma
TIJUANA
UNITED STATES
MEXICO
Pta. Descanso
Pta. Salsipuedes
ENSENADA
Pta. Banda
Pta. Santo Tomás
Pta. Cabras
1
2
3
4
5
6
7
8
9
10
Gulf of Santa Catalina
San Diego Trough
Thirtymile Bank
Fortymile Bank
San Clemente
Coronado Bank
Los Coronados
Descanso Basin
Descanso Plain
San Clemente Basin
Salsipuedes Knolls
Cortes Basin
Ensenada Trough
Maximinos Knolls
San Isidro Ridge
Animal Basin
kilometers
Contours in Meters



Day 1

Saturday October 21, 1989

Start of Road Log

UCSD, San Diego, California

Depart west from Lot #305 at the University of California, San Diego on an international bus. Turn south on North Torrey Pines Road and southwest on La Jolla Shores Drive to the Scripps Pier. Breakfast will be served on Scripps Pier.

Field Trip Stop #1

Scripps Pier

Faulting and Seismotectonics of the Inner Continental Borderland West of San Diego

Speaker: Mark R. Legg

The inner California Continental Borderland west of San Diego is underlain by two, major, northwest-trending, dextral wrench fault systems: the Agua Blanca fault system and the San Clemente fault system (Figure 1). These fault systems are an active part of the modern Pacific-North America plate boundary. Large earthquakes on the San Clemente fault system, located farther to the west, or moderate to large earthquakes on the offshore Agua Blanca fault system could be destructive to San Diego and other coastal communities. Because accurate slip rates are unknown for these offshore faults, the relative seismic risk posed to San Diego by the individual fault zones is unknown at present. Preliminary estimates of the overall offshore slip rate, based upon measures of the slip on the transpeninsular Agua Blanca fault and Navstar satellite (GPS) geodesy show significant movement, 1-13 mm/yr, although the uncertainty is high (Rockwell et al., 1987; F. Webb, personal communication, 1989).

Consistent with the San Andreas fault system and the Pacific-North America plate boundary, inner borderland fault zones show mostly right slip along northwest-trending faults. The slip vector for the long, continuous, and well-defined San Clemente fault system (N40±3°W) is parallel to that of the present day Pacific-North America relative motion vector. Major bends or offsets in the San Clemente-San Isidro fault zone are the sites of substantial dip-slip and structural relief. The complex offshore Agua Blanca fault system is inferred to be a broad zone of dextral oblique shear, with transtension along its southern part and transpression along its northern part. Oblique slip during large offshore earthquakes could displace the seafloor and generate local tsunamis that would be directed toward the San Diego coast.

Complex, yet systematic, variations in the fault character of the inner borderland suggest a tectonic model of the southern California region as a broad shear zone representing the splintered northern end of a long, narrow, Baja California microplate. Impact of this microplate against the Transverse Ranges and curvature of the San Andreas fault through the Transverse Ranges forces a counterclockwise rotation of the Southern California Shear Zone explaining the transtension in the southern part of the offshore Agua Blanca fault system and transpression in the northern part. The transpeninsular Agua Blanca fault acts as an intracontinental transform fault connecting the extension in the inner borderland with that in the Gulf of California. The San Diego area is located near the center of the deforming Southern California Shear Zone, where the transition from transtension to transpression is presently occurring. The intersection of three major fault zones, occurs at the southern end of San Diego Bay creating a very complex tectonic environment. As the plate boundary continues to evolve, with increased convergence of the southern California region into the Transverse Ranges, the character and rate of faulting in the San Diego area is expected to change dramatically.

(References listed in preceding text report by Mark R. Legg.)

Inner Continental Borderland
Principal Late Cenozoic Faults

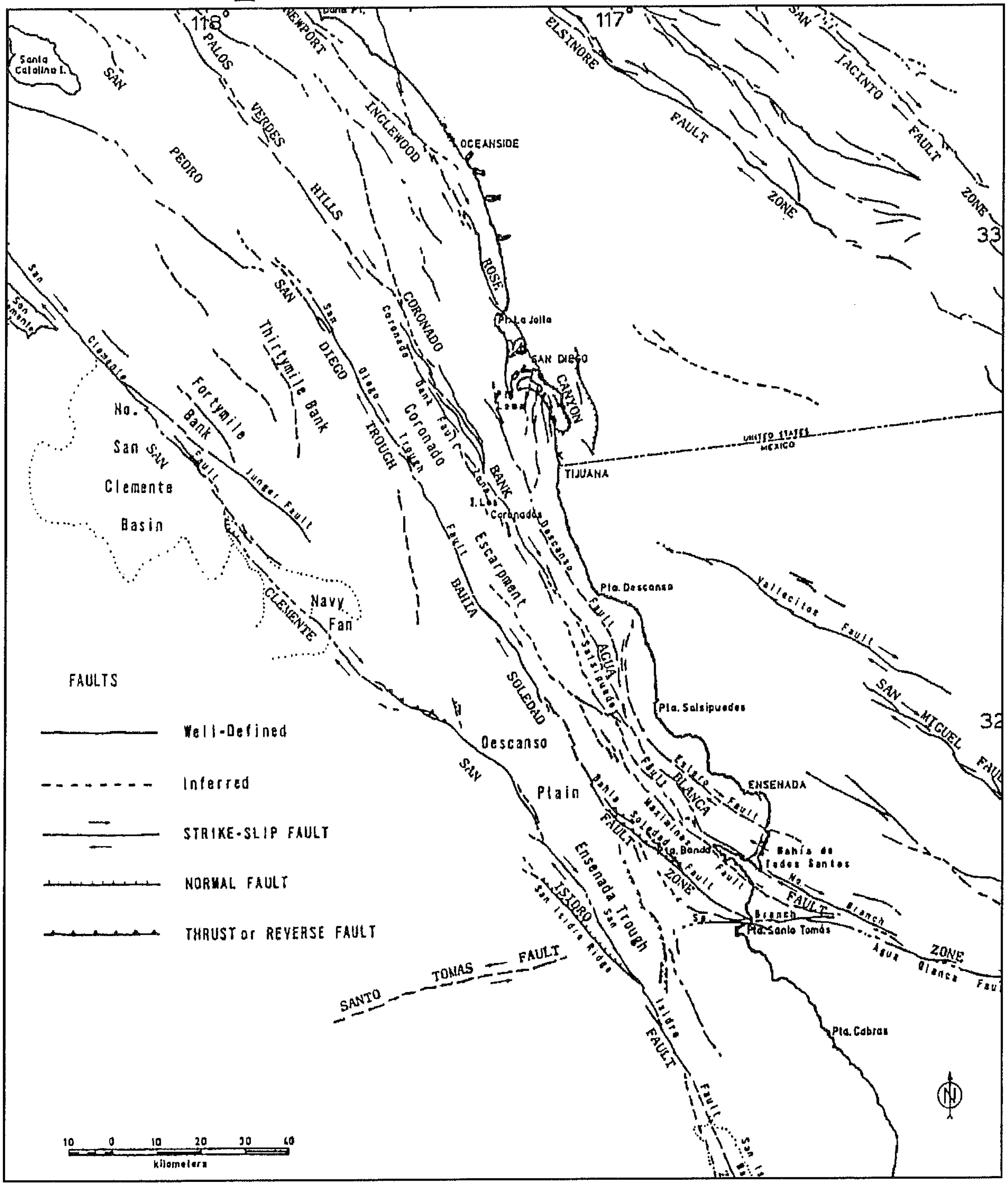
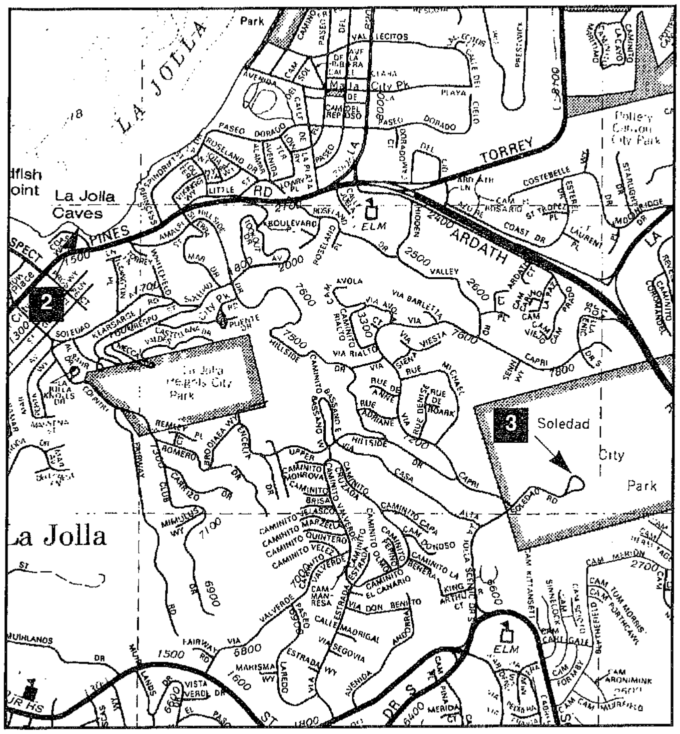


Figure 1.

Map showing the principal late Cenozoic faults of the inner California Continental Borderland and adjacent regions of southern California and northern Baja California. The offshore faults have been divided into two major fault systems: San Clemente fault system and Agua Blanca fault system. Both offshore fault systems are right-slip in character, although dip-slip is locally important in many areas as shown by the large seafloor relief. Fault data are compiled from many sources: Moore (1969); Vedder et al. (1974); Gastil et al. (1975); Kennedy and Welday (1980); Kennedy et al. (1980a and b); Legg (1985); and the California Division of Mines and Geology map sheets.



Head south on La Jolla Shores Drive, turn west on Torrey Pines Road to the intersection of Prospect Street. North of this intersection is La Jolla Caves in La Jolla Bay. Hike down the sea cliff to the Country Club fault shear zone.

Field Trip Stop #2
La Jolla Caves

Country Club Fault, Rose Canyon Fault Zone

Speaker: Diane Murbach

Exposed in the sea cliff is the Country Club fault shear zone within the Cretaceous Point Loma Formation. This is the western mapped fault in the Rose Canyon fault zone. A thick fault gouge can be seen in this near vertical exposure. The Country Club fault which extends across the south flank of Mt. Soledad from La Jolla Bay to the mouth of Rose Canyon was described by Kennedy and others (1975) and Kies (1979) as a reverse fault, down to the west, displacing sediments as young as Lindavista Formation but not displacing Bay Point Formation.

Return to Torrey Pines Road and turn south and weave southwest up Mount Soledad to the Easter cross in Soledad Park.

Field Trip Stop #3
Mount Soledad Park

Rose Canyon Fault System

Speaker: Diane Murbach

The geomorphic expression of the Rose Canyon fault system is evident from topography. Point Loma to the south and Mount Soledad are topographic highs while Mission Bay and San Diego Bay are lows. The main trace of the on-shore portion of the Rose Canyon fault follows Rose Canyon along the east side on Mount Soledad.

Head south to Soledad Mt. Road and turn east on Garnet Avenue. Just to the north of Garnet Avenue as you cross Mission Bay Drive, is the location of the SDG&E operation facility on Damon Avenue. At this location in June 1989, Tom Rockwell, Scott Lindvall and Greg Unruh trenched a strand of the Rose Canyon fault zone. The trench was located on a low Holocene fan-terrace of Rose Creek. This site was chosen based on 1928 and 1941 photos. The fault zone mapped in the trench was about 2m wide and reportedly was comprised of multiple breaks that displaced strata in Holocene alluvium. Based on conversations with Tom Rockwell, at the time of this field trip, samples taken for age dating had not been complete. Based on their trenching study, they suggested evidence of M6+ surface rupturing earthquakes.

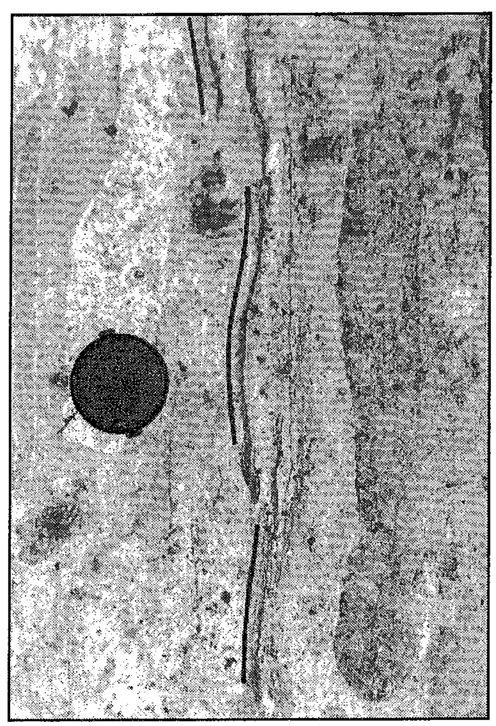


Figure 2

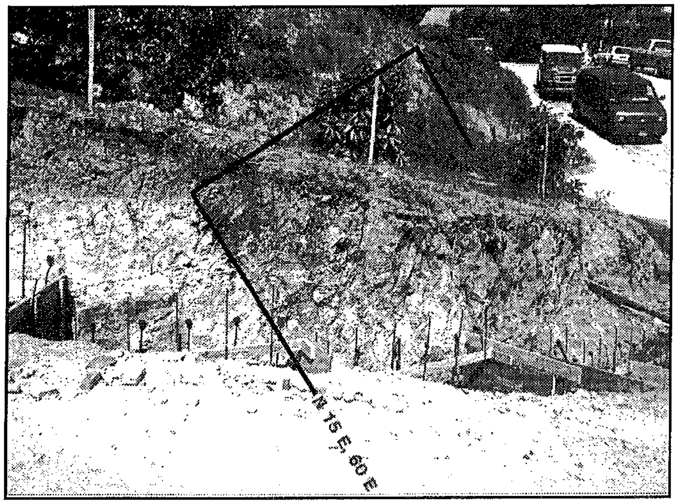
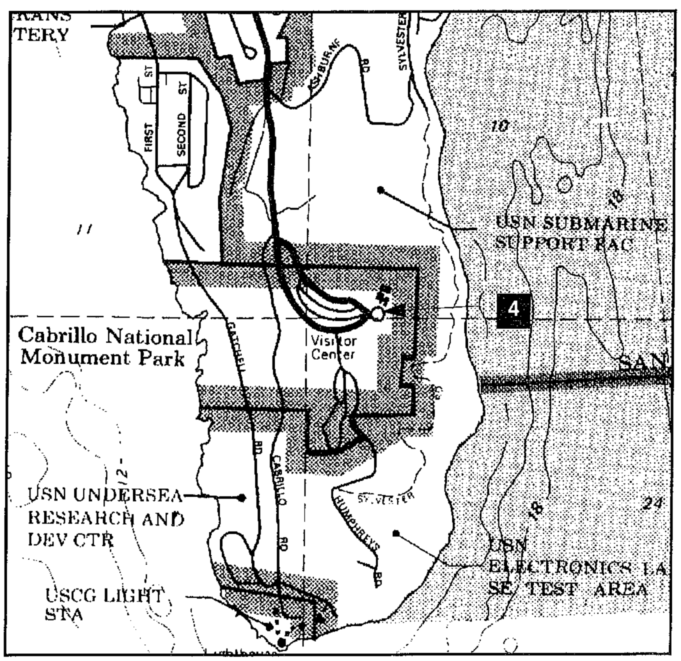


Figure 3

Turn south on Morena Boulevard following the Rose Canyon fault system to east Mission Bay. Trenching and mapping east of Morena Boulevard and north and south of Clairemont Drive by Monte and Diane Murbach, encountered a north-south trending sympathetic high-angle fault and fracture system (Figure 2). One exposure on the main Rose Canyon fault trace suggested an apparent west-side-up vertical separation trending N15E, dipping 60 east. The Eocene Scripps Formation can be seen faulted up to the west against the Pleistocene Lindavista Formation, down to the east (Figures 3).



Continue south on Morena Boulevard, turn west on Tecolote Road, cross I-5 and continue on SeaWorld Drive to Sunset Cliffs Boulevard. Turn southeast on Point Loma Avenue, then south on Catalina to Cabrillo National Monument. Lunch will be served with a panoramic view of San Diego and the Pacific Ocean.

Field Trip Stop #4
Cabrillo Monument

Gravity Studies of the Point Loma-Spanish Bight-Coronado-Silver Strand Fault Zones

Speaker: Monte Marshall

INTRODUCTION

Detailed gravity traverses, presented in a paper in the forthcoming proceedings of the San Diego Seismicity Conference, support Kennedy et al.'s (1975) suggestion that the San Diego basin is a nested graben in a zone of tension between two offset strands of the Rose Canyon fault. A number of important consequences follow from such a genetic connection between the predominantly dip-slip faults bounding the graben, or rhombochasm, and the predominantly strike-slip Rose Canyon fault to the north and its southern continuation into Mexico. The fault systems are equally active or inactive, in the sense that any slip on the Rose Canyon fault must ultimately result in slip on the graben faults and vice-versa. Secondly, the faults bounding the western margin of the graben are most likely as active as those on the east, i.e., the La Nacion fault zone. However, since they are largely underwater or are buried by alluvium, much less is known about the faults between Pt. Loma and the center of the basin, beneath San Diego Bay. Most of the gravity traverses made so far in this region have concentrated on the La Nacion fault zone. There are two detailed gravity profiles which cross the axis of the graben and extend for several miles on the west side. The purpose of this article is to discuss the information that these two traverses provide, when combined with the regional gravity data, on the faults bounding the western side of the graben.

Geology

Much of what is known about the faults on the west side of the San Diego basin is due to Michael Kennedy. Three, down to the east, en echelon fault zones were mapped by Kennedy and Welday (1980) west of Silver Strand with high resolution seismic profiling (Fig. 4). A number of northerly trending, usually down to the east faults have also been mapped on Pt. Loma peninsula and between Ocean Beach and Loma Portal in the vicinity of Nimitz Blvd. (Kennedy et al., 1975; Kennedy, 1975; Fig. 4).

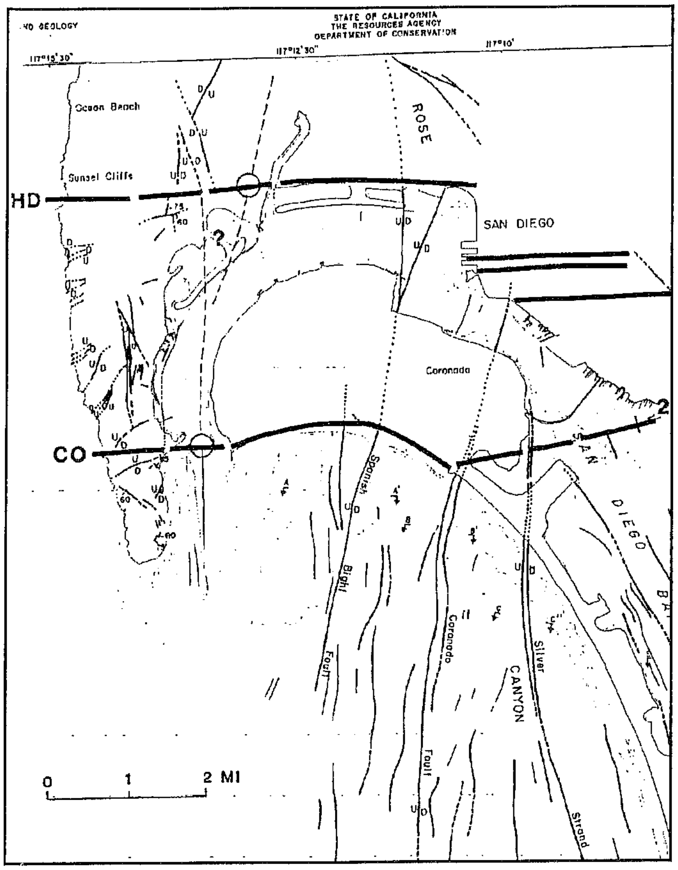


Figure 4

Map showing fault traces in San Diego Bay, offshore Silver Strand, and on Pt. Loma (Kennedy and Welday, 1980 and Kennedy, 1975) and location of gravity profiles. Solid lines are detailed studies with a station spacing of about 500 feet. Dashed lines show portions of profiles where gravity values were estimated from regional Bouguer anomaly maps. HD-IM, Harbor Drive traverse with extensions west to the coast and east through downtown San Diego and along Imperial Ave. CO-28, south shore Coronado traverse with extensions west to the coast and east to the 28th St. pier. Circles are fault locations suggested by the gravity data. Long dashed lines near the circles are possible fault traces.

Gravity Studies

The northernmost of the E-W profiles discussed here consists of a detailed, three mile long traverse along Harbor Drive from Pacific Coast Highway to one mile east of the Lindberg Field terminals. This gravity profile is extended another three miles to the coast using the Bouguer anomaly contour map of Biehler (1982; Figs. 4 and 5). The middle profiles consist of two detailed traverses in downtown San Diego and a six mile long detailed traverse along Imperial Ave. from the bay east to the La Nacion fault zone. The southern profile is a detailed, three mile long traverse along the south shore of Coronado from Zuniga Pt. to the Hotel Del Coronado. This profile is extended west two miles to the coast and east three miles to the 28th St. Pier using the Bouguer anomaly contour maps of Biehler (1982) and Sullivan (1983).

The Harbor Drive—Imperial Avenue Profile

A composite profile extending from the coast to the La Nacion fault zone shows the structural graben of the basin with downtown San Diego on its axis (Fig. 6). To the east the steps in the gravity curve correspond well to the mapped traces of the La Nacion fault zone. The western half of the profile is notable in what it shows and doesn't show. The flatness of the gravity profile on the eastern half of Harbor Drive and in downtown San Diego shows that the Spanish Bight and Coronado fault zones, which are responsible for most of the throw on the western side of the graben only several miles to the south, have little displacement this far north. A small, down to the east, step in gravity near the Harbor Island overpass and along Kettner Blvd. at the west end of the Broadway and Market profiles may be due to near surface displacements on two, still active, strands of these fault zones.

The fault zone responsible for most of the structural relief on the west side of the graben is centered near the intersection of Rosecrans and Harbor Drive. The gravity data has been corrected for the 2 to 3 mgal/mile westward increase expected for a 5 to 10 degree basement slope underlying the eastwardly

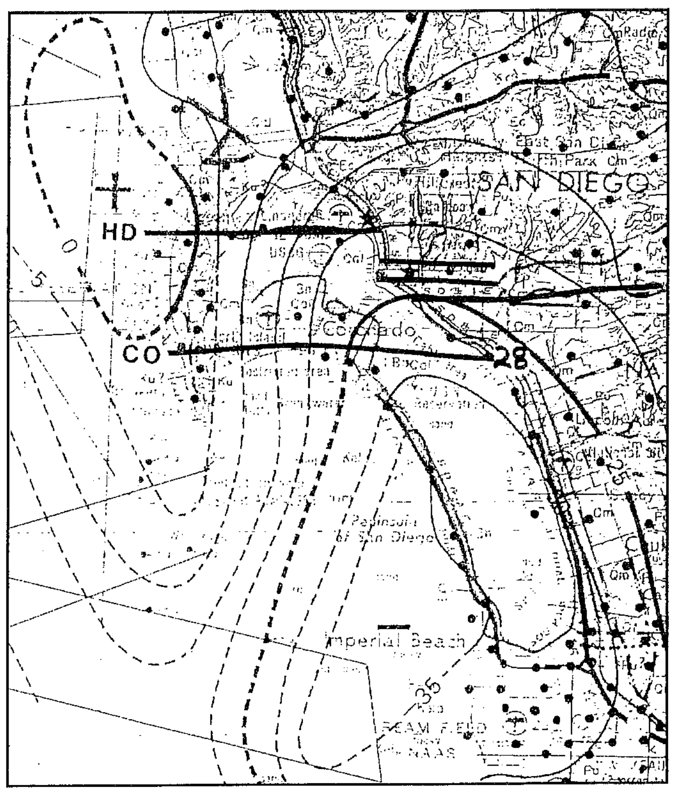


Figure 5

Biehler's (1982) Bouguer anomaly map of the San Diego area (actually compiled by him in 1979 and based largely on data from Elliott (1970), showing locations of composite gravity profiles used in this study. Contour interval is 5 mgals. Data taken from this map has been reduced by 1.5 mgals in accordance with the revised California gravity network values (Oliver, 1980).

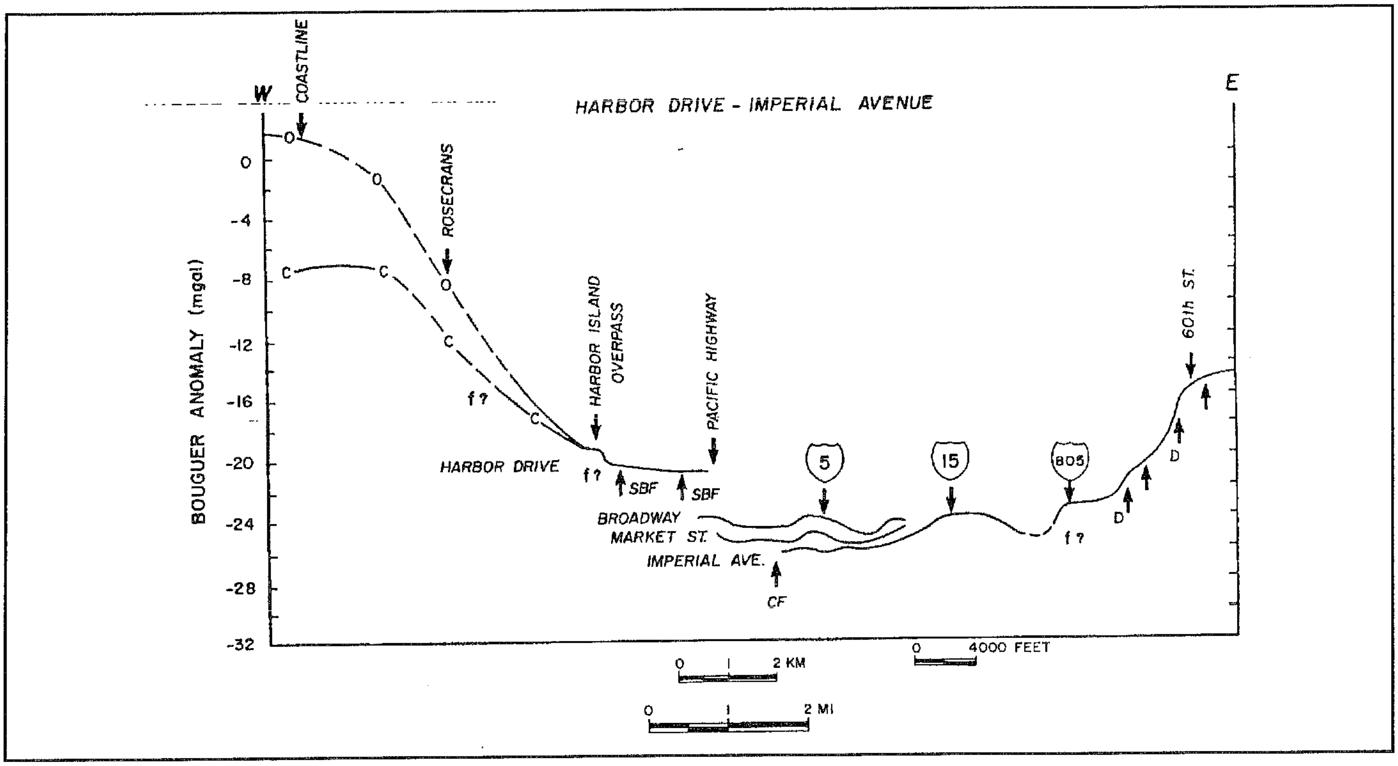


Figure 6

Bouguer anomaly profiles of the detailed survey measurements along Harbor Drive, Broadway, Market, and Imperial Ave. (solid lines) and data from the Bouguer anomaly contours in Fig. 2 (dashed line and O's). C, gravity values corrected for the 5 to 10 degree easterly dip of the sedimentary rocks in the Pt. Loma area. SBF and CF, northward extensions of the Spanish Bight and Coronado faults, respectively. Unlabeled arrows at the eastern end are locations of strands of the La Nacion fault zone with the downthrown side indicated.

dipping sedimentary rocks in this area (Kennedy, 1975). Assuming an average density contrast of 0.3 gm/cc, the 12 mgal step here corresponds to about 3000 feet of throw, making this the major fault in uplifting the Pt. Loma block.

Since much of the gravity curve here is based on map contours, the exact location of the fault zone is uncertain. The intersection of Rosecrans and Harbor Drive is exactly on line with the NNW trending Pt. Loma fault mapped by Kennedy (1975) along Nimitz Blvd. (Fig. 4). However, outcrops of the 500 to 1000 feet thick Cretaceous Cabrillo sandstone mapped by Kennedy (1975) on both sides of this fault just 2000 feet north of the intersection make the Pt. Loma fault an unlikely candidate for such a major fault. The center of faulting suggested by the gravity lies about 2000 feet west of Rosecrans.

The northward continuation of this fault is also unknown. East-west gravity traverses on Barnett Ave. and along the middle jetty to the north show that the throw on the fault zone continues to be several thousand feet one mile to the north but almost disappears two miles to the north at the jetty (Marshall, 1989). The westward extension of the Barnett Ave. profile, using the anomaly contours, to the coast suggests the fault zone lies in Loma Portal, about 0.5 mile east of Kennedy's Pt. Loma fault. Outcrops mapped as Cretaceous and Eocene between these two faults also suggest that the major throw occurs on the east and not on Kennedy's Pt. Loma fault. This major, gravity-suggested fault bounding the east side of the Point Loma block will be referred to as the East Pt. Loma fault.

The South Shore Coronado Profile

Three miles south of Harbor Drive most of the structural relief on the west side of the graben is due to the Coronado and, especially, the Spanish Bight fault zones (Fig. 7). Assuming a density contrast of 0.3, they account for about 3000 feet of throw. The gravity data suggest the fault zone bounding the Pt. Loma block lies between Ballast and Zuniga Points and has about 2000 feet of throw, about 1000 feet less than to the north. Whether this fault joins the Pt. Loma fault or the more significant East Pt. Loma fault is not known. Given the small amount of throw on the Pt. Loma fault mentioned above, and the north-northeasterly trend of the Spanish Bight and Coronado faults in this area, the fault probably connects to the East Pt. Loma fault.

Comparing this profile with the one to the north, the faults display the same, discontinuous, en echelon behavior observed in the La Nacion fault zone

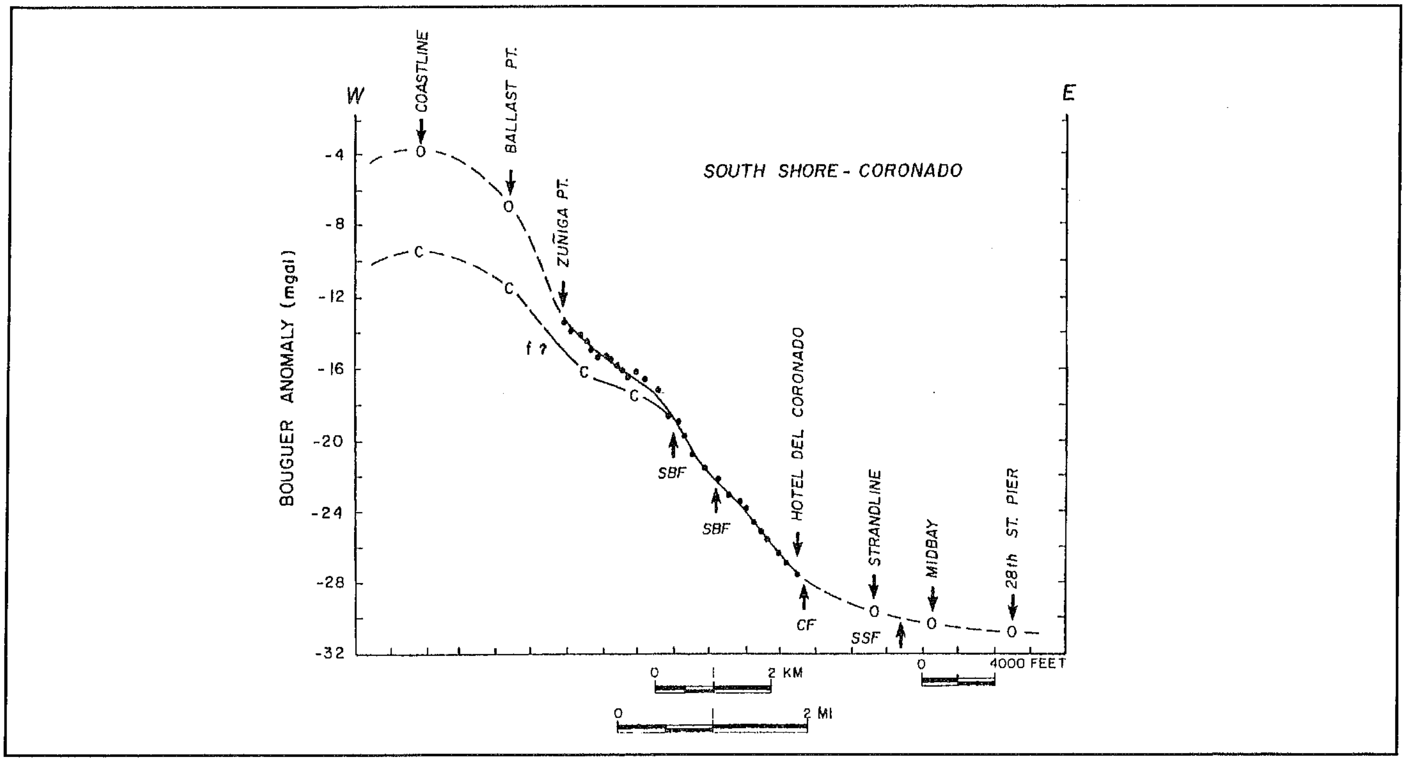


Figure 7

Bouguer anomaly profile composed of detailed survey measurements along the south shore of Coronado (solid line through measured values) and data extrapolated to the coast using the Bouguer anomaly contours of Fig. 2 and extrapolated across San Diego Bay using the Bouguer anomaly map of Sullivan (1982)—dashed lines and O's. SSF, Silver Strand fault. All other symbols as in Fig. 3.

(Marhall, 1979). As the Spanish Bight and Coronado faults die out to the north, the slip is taken up by the Pt. Loma fault zone. Even the topography of the Pt. Loma block corresponds generally to the amount of throw on the East Pt. Loma fault. The elevation of the peninsula falls to sealevel at the northern end of the fault. The peninsula is highest near Ballast Point but its southern end may result from a combination of wave erosion and the southward dying out of the fault.

Summary and Conclusions

The faults offshore of Silver Strand and that bound the Pt. Loma block form the western half of a N-S trending graben centered under San Diego Bay and are the mirror image of the La Nacion fault zone on the east (Fig.8). Like the strands of the La Nacion fault, these faults are discontinuous and en echelon. They step left from the Silver Strand fault zone on the southeast to the Pt. Loma fault zone on the northwest. The dip slip is probably greatest near the center of each zone and dies out at each end. The dip slip on the Silver Strand fault zone is probably greatest offshore of Imperial Beach. Much of the basin depth at its center is probably due to slip on the Coronado and Silver Strand fault zones. At Coronado the Spanish Bight is the major fault zone. And in the Lindberg Field area the major fault is the East Pt. Loma fault. Based on composite gravity profiles and the local geology, this fault zone begins near the San Diego River, extends south thru Loma Portal, the Naval Training Center, and Shelter Island, goes between Ballast and Zuniga Points, and probably dies out several miles to the south. Opposite to Kennedy's (1975) cross-section , there is about 3000 feet of down to the east throw on the Pt. Loma fault zone.

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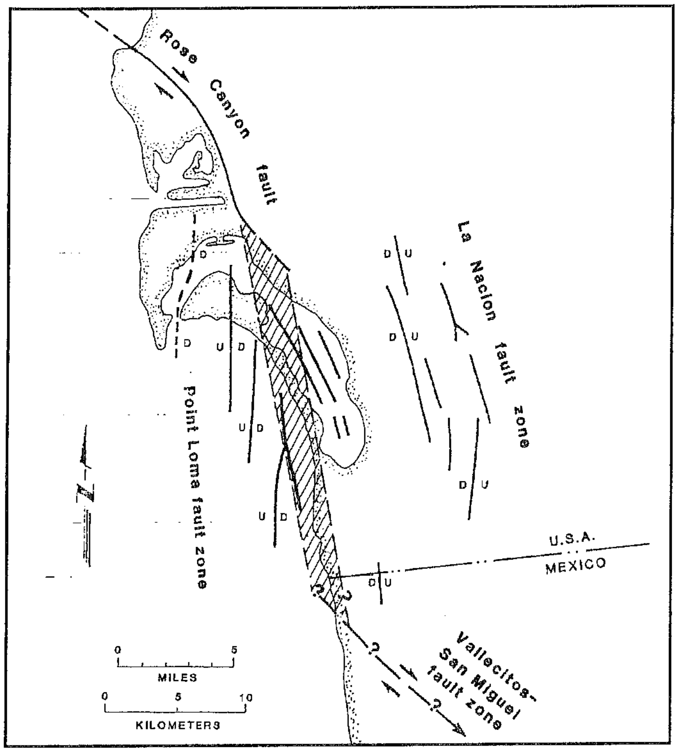

Figure 8

A simple rhombochasm model for the generation of the San Diego basin. As the Pt. Loma - Mt. Soledad block moves northwest, a N-S zone of the mid-lower crust beneath San Diego Bay stretches and thins—creating a depression into which pieces of the upper crust slide. This zone of crustal extension and large scale crustal 'slumping' is about 14 miles wide. The hachured zone merely shows the center of extension and the rhombohedral shape of the chasm that would be created if the crust behaved rigidly. The en echelon nature of the three fault zones offshore Silver Strand is shown as well as the possible location of the major strand of the Pt. Loma fault zone.

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Acknowledgments

I thank and acknowledge my SDSU senior thesis students, Steve Dolan, John Harrington, Rick Lothamer, Dennis Sullivan, and Curt Tandy who spent many hours taking and reducing the gravity data presented here. Their interest and careful work made this report possible. I also thank Teresa Larson for her excellent drafting and Diane Rice for her excellent typing.

Head north on Catalina Blvd., west on Talbot St., northeast on Rosecrans, east on North Harbor Drive, south on I-5 and east on 94. Turn south on I-805 following the trend of the La Nacion fault system to Otay Mesa.

As we proceed south on I-805, good views of the Otay Valley landslide (Figure 8A) begin just beyond the Orange Avenue overpass, on the left (east) side of the bus. This approximately 7,500 feet wide, 3,000 feet long, ancient landslide is located on the south side of Otay Valley, just east of the intersection on I-805 and Palm Avenue. Geomorphic expression includes: a highly eroded arcuate back-scarp area, hummocky topgraphy, and a distinctive bulging toe which protrudes into the south side of the Otay River bottom. After persisting in drilling through "good formation" for 92 feet, older alluvial deposits were encountered under the landslide toe. A minimum age of 25,900 years BP was obtained by radiocarbon age dating of organic material collected from a bucket auger sample of the buried alluvium. Good exposures of the La Nacion fault have been found within this approximately 200 acre slide mass; it has yet to be determined, however, which one moved most recently (Elliott, 1989).

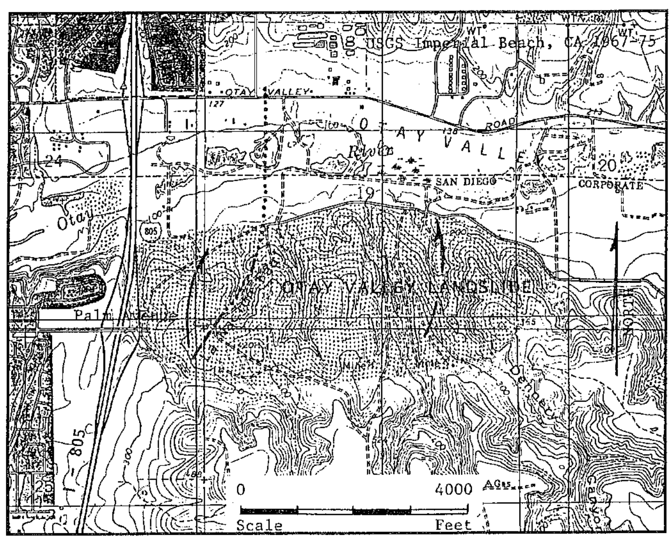


Figure 8A

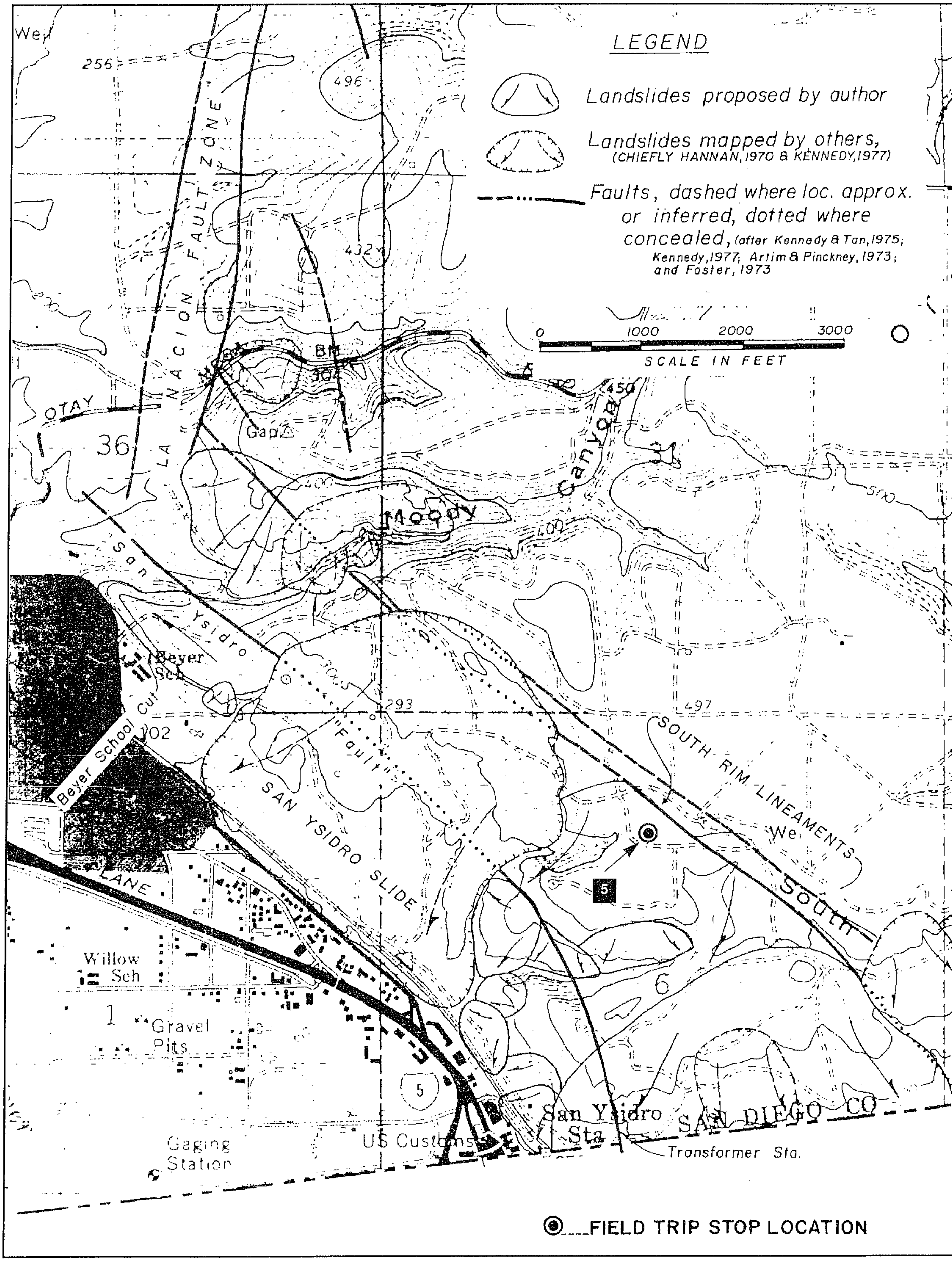


Figure 9 **FAULT AND LANDSLIDE MAP OF SAN YSIDRO AREA**
(HART, 1977)

Field Trip Stop #5
Otay Mesa

Faults and Landslides

Speakers: Tom Kuper &
Dorian Elder Kuper

The stop is located on the South Rim of Otay Mesa overlooking the San Ysidro Slide Complex and the South Rim Lineaments mapped by others as indicated on the attached Figure 1. The purpose of this stop is to discuss the stratigraphy and faulting in the South Bay Area of San Diego County, as well as examine evidence that suggests that landsliding processes might provide a better explanation of the features in the South Rim Lineament Area.

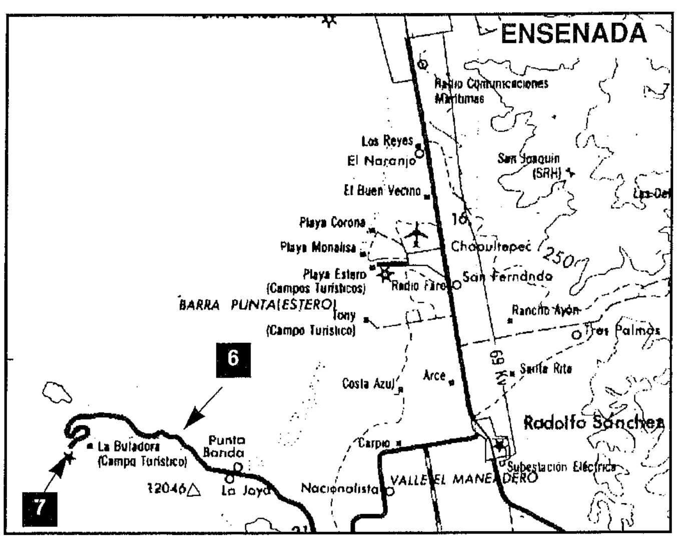
Load the bus and head southeast to the Otay Mesa International border crossing. After crossing the border, head west towards Tijuana and the Mexican "Toll Road" (Ensenada Quota) highway for Ensenada, Mexico. Saturday night Mexican dinner buffet and accommodations are at the Hotel Misión Santa Isabel in Ensenada. ¡Buenas Noches!

Day 2

Sunday October 22, 1989

¡Buenos Días!

After a Sunday Champagne Mexican brunch, load the bus and head southward and west for the Punta Banda area. This drive will take you through the Agua Blanca fault zone. Several faults cross the Punta Banda peninsula and appear to be synthetic to the Agua Blanca and Maximinos strands of the fault zone.



Turn north on a dirt road to a boat launch at the sea cliffs west of the small community of El Rincon.

Field Trip Stop #6
North Side of Punta Banda Peninsula

Rudistid Pelecypods and the Rincon Fault

Speakers: Diane Murbach &
James R. Ashby

The best exposures of the rudistid pelecypod <u>Coralliochama</u> <u>orcutti</u> are found here in the upper Cretaceous Rosario Formation sea cliffs. The rudists are in chaotic orientations and have been associated with reef or storm deposits. Walk west along the sea cliffs to the Rincon fault exposure which has been dated by Tom Rockwell et. al. (1989). Reportedly this fault appears to cut into the "A" horizon surface soil and may fault Indian midden deposits, suggesting Holocene movement. Rockwell et. al. (1989) have shown the fault to have 9m of vertical separation across the sea cave terrace.

Return to the paved road and head west on the Punta Banda peninsula for La Bufadora.

Field Trip Stop #7
La Bufadora, Baja California

La Bufadora Blow Hole

Speakers: Diane Murbach &
James R. Ashby

This is a natural phenomenon known as La Bufadora (from Bufar, to snort). This feature is similar to the ones found in the Caymen Islands. The force of the waves drives water through a narrow opening in the rocks with enormous force and tosses it up to a height of 20m (65 ft.), creating a thunderous noise. This is caused by incoming water sealing off and compressing the air inside the cave. This compressed air forces an air-water mixture out of the mouth of the cave and blows it up and outward.

These rocks have been mapped as part of the pre-batholitic Alistos Formation sedimentary unit. (Gastil, Phillips and Allison, 1971).

Return eastward to Mexican Highway 1. Turn north and head to Medio Camino, the half way house above the sea cliff between Ensenada and Rosarito, Mexico. Lunch will be served at the half way house.

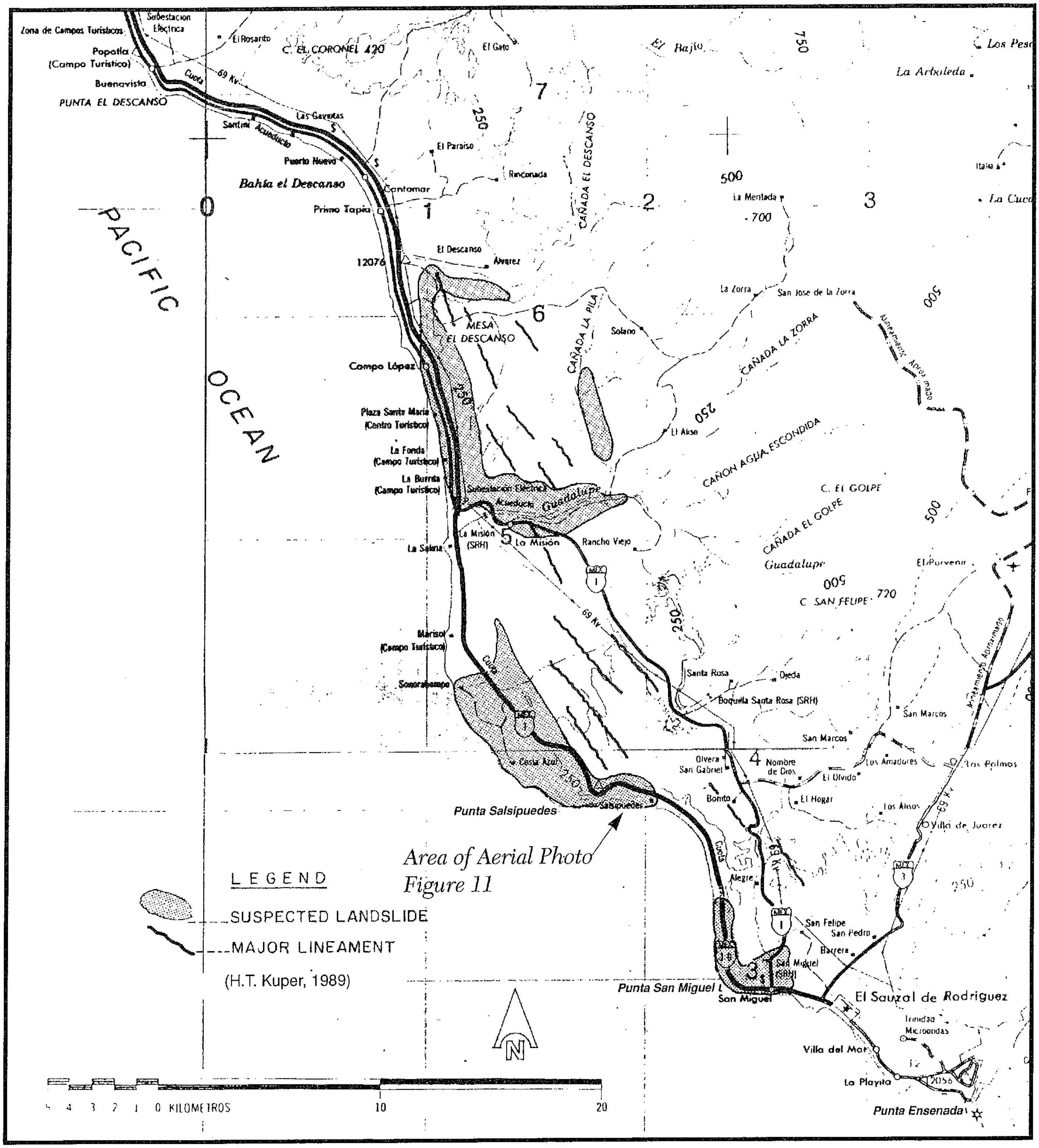


Figure 10

Punta Salsipuedes

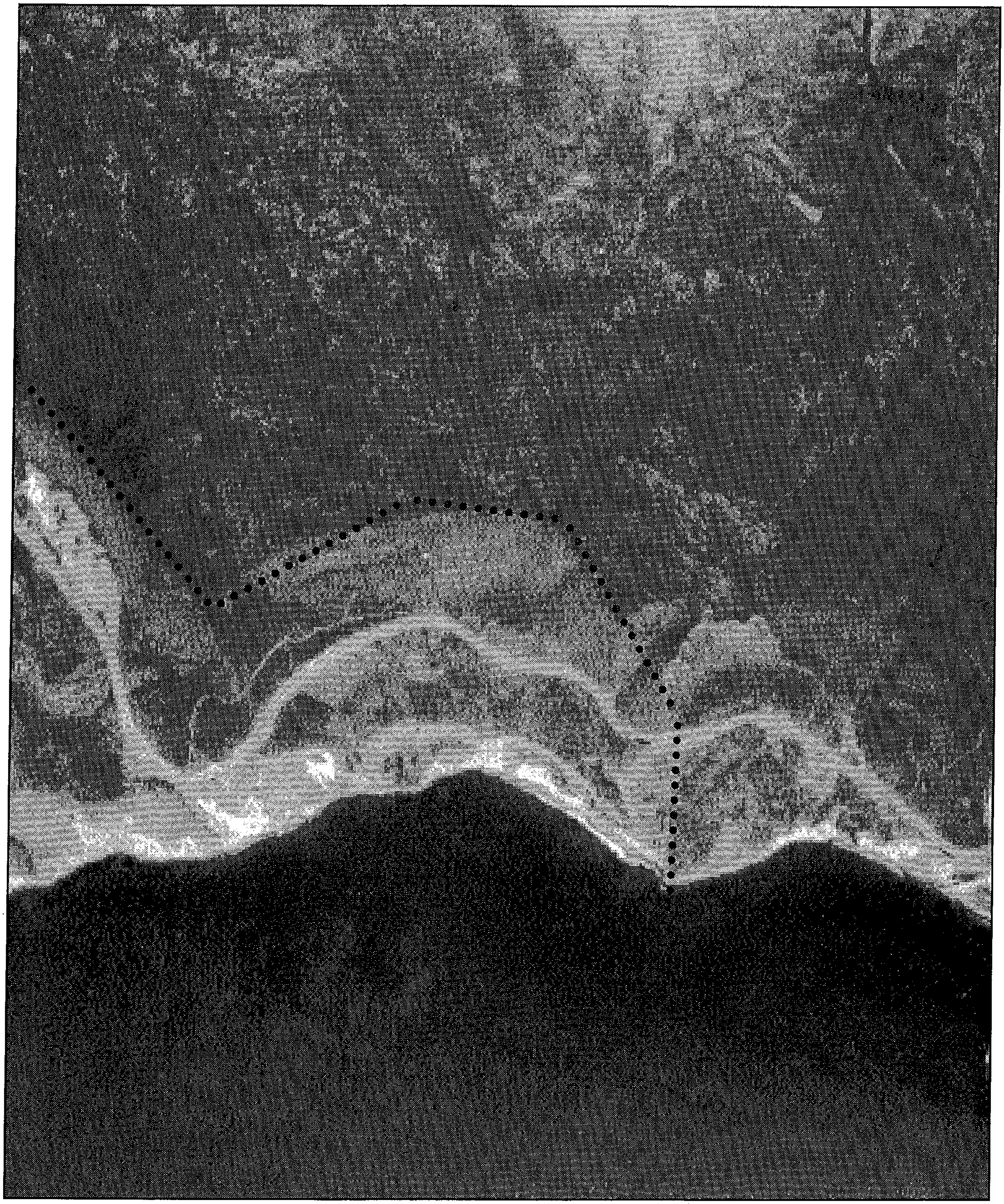
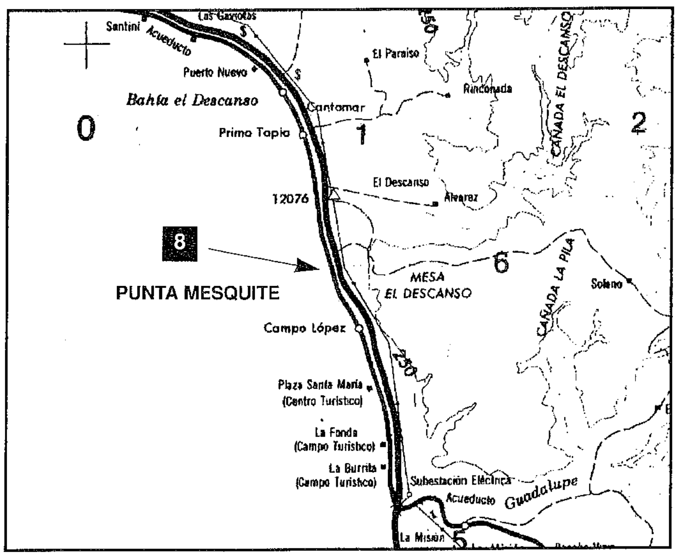


Figure 11

Presents an aerial view of one of the Punta Salsipuedes landslides.

Approximately 10 miles north of Ensenada along Mexican Highway 1 is the Punta Salsipuedes area. As we drive though this area, note the hummocky topography and lineaments. The Punta Salsipuedes area is underlain by sediments of the Cretaceous Rosario Formation and capped by basalts of the Middle Miocene-age Rosarito Beach Formation. Quaternary-age marine terrace deposits are found at lower elevations adjacent to the existing coastline. Exposed within the Punta Salsipuedes area the Rosario Formation consists predominately of mudstones interbedded with sandstones and conglomerates (Yeo, 1984). The basalts of the Rosarito Beach Formation uncomformably overlie the Rosario Formation with the contact between the two formations dipping generally to the west.

Within this area, numerous composite landslides can be recognized. These include large-scale rotational slumps and translational slides incorporating both the Rosario and Rosarito Beach Formations. Also major lineaments have been recognized within the basalt which are probably associated with previous fault activity and possible landslide movement (Figure 10 and 11).



Field Trip Stop #8

Medio Camino, Baja California

Middle Miocene Strata of the Medio Camino Member of the Rosarito Beach Formation

Speakers: James R. Ashby & John A. Minch

INTRODUCTION

The section is best viewed by leaving the parking area and climbing down from the upper Pleistocene marine terrace via the stairway, down onto the beach. Exposed here is the type section of the Medio Camino Member of the Rosarito Beach Formation. This member is underlain to the south by the stratigraphically lowest member of the Rosarito Beach Formation, the Punta Mesquite Member, and is overlain by the extensive basalts which form the prominent mesas that can be observed to the east (Figure 12).

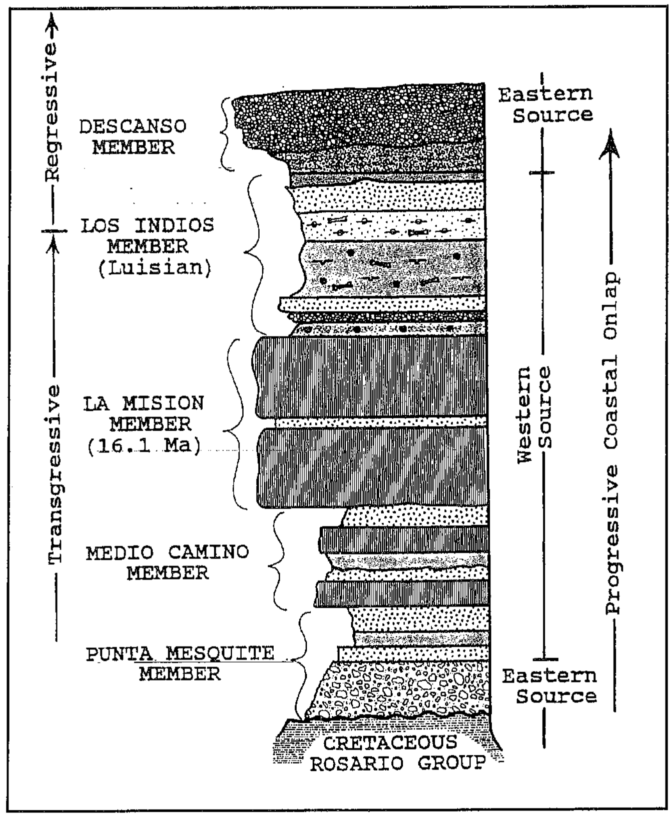
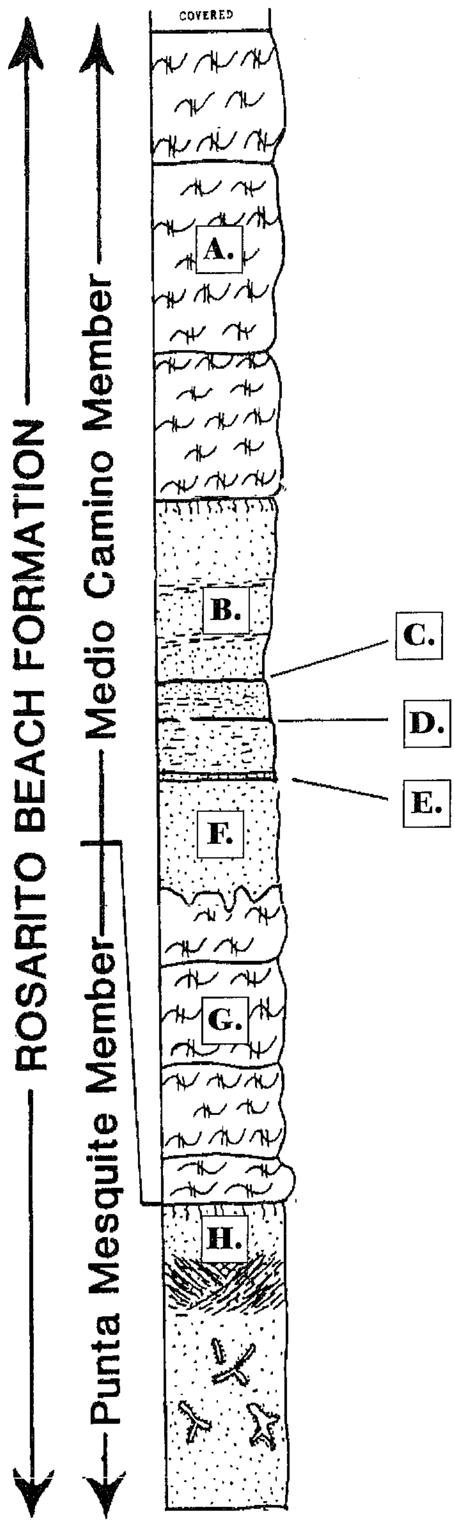


Figure 12

Composite columnar section of the Miocene Rosarito Beach Formation in the La Mision Sub-basin of the Rosarito Beach basin (from Ashby and Minch, 1988; Ashby, 1989).

The Medio Camino Member of the Rosarito Beach Formation is continuously exposed along the beach between Punta Mesquite (1km south) and Medio Camino, and then discontinuously north to the cemetery on the southern side of Canon El Descanso. This member is also exposed farther south along the coastline between Marisol and Punta Salsipuedes, and in a fault-bounded sequence on Islas Todos Santos in Ensenada harbor (Ashby, 1989).

The type section of this member is designated as the outcrops along the coastline beginning at Punta Mesquite and extending through Medio Camino and north to the cemetery on the south side of Canon El Descanso. The Medio Camino Member conformably overlies the Punta Mesquite Member at Punta



A. BASALT, reddish-brown, pyroxenes completely oxidized to clay, plagioclase phenocrysts to 8 mm, abundant vesicles to 1.8 cm.

B. LITHIC CRYSTAL TUFF-SANDSTONE, white to light gray, massive to poorly bedded angular to sub-angular, moderately to well sorted, contains interbeds of CRYSTAL TUFF, light brownish-gray, very fine-grained, thinly laminated, angular to very angular, well sorted, devitrified, bright pink baked zone in upper part.

C. LITHIC CRYSTAL TUFF-SANDSTONE, light greenish-gray, very fine–to fine-grained, very thinly bedded angular to very angular, well sorted.

D. LITHIC LAPILLI CRYSTAL TUFF-SANDSTONE, light gray, fine-grained, thinly laminated, angular to very angular, very well sorted.

E. CRYSTAL TUFF, white, very fine-grained, thinly laminated, very angular, very well sorted, 10 cm thick, partially divitrified.

F. LITHIC LAPILLI TUFF-SANDSTONE, light gray, very fine-grained in lower part, fine-grained in upper part, massive, angular to very angular, very well sorted, contains brown, devitrified mud/ash rip-ups in upper part.

G. BASALT, reddish-brown to black, pyroxenes are oxidized to a bright reddish-brown, plagioclase phenocrysts to 3.0 mm in lower part and to 1.5 mm in upper part, moderate vesicles in lower part to rare vesicles in upper part.

H. LITHIC CRYSTAL LAPILLI TUFF-SANDSTONE, white to light gray, fine-grained, massive to poorly bedded in upper part, angular, well sorted, contains burrows of Omphiomorpha, pink-oxidized baked zone in upper part.

Figure 13

Measured section along the beach from Punta Mesquite north to the Medio Camino area (modified from Ashby, 1989).

Mesquite where it consists of a 6.1 to 9.1 meter basal basalt, 9.8 meters of tuffaceous sediments and 12.2 meters of capping basalt (Figure 13).

Lower Basalt

The lower basalt present at the south end of the cove at Medio Camino, consists of 6.1 to 9.1 meters of black to reddish brown basalts which have baked and oxidized the underlying Punta Mesquite Member to a bright reddish-brown color. The upper surface of the lower basalt unit contains pahoehoe ropes (flow structures) which indicate the general flow direction was to the east and northeast.

Middle Tuff

The overlying tuffaceous unit present here in the sea cliffs consists of 2.7 meters of light gray to gray lapilli tuffs, containing mudstone and ash rip-ups. A prominent 10-centimeter thick white ash bed interrupts the section, which then is succeeded upsection by 7.0 meters of greenish-gray to buff, thinly bedded to locally-massive crystal tuffs. The upper unit is baked to a bright reddish-brown color by the overlying basalt.

Upper Basalt

The upper basalt is present in the sea cliffs along the beach below Medio Camino and consists of up to 12.2 meters of red-brown, very highly scoriaceous basalt. Pillow structures are absent and the upper

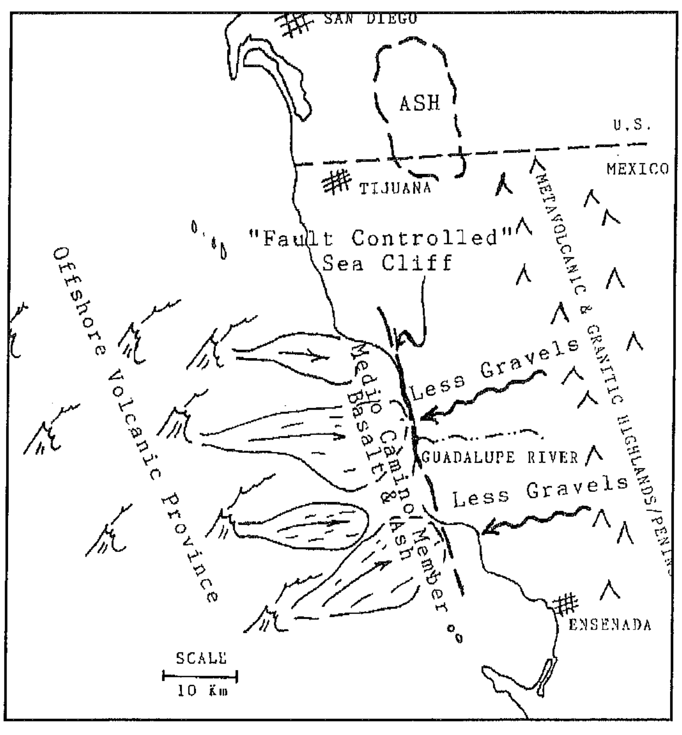


Figure 14

Paleogeography during deposition of the Medio Camino Member of the Rosarito Beach Formation, ?Zemorrian - Relizian (?23-16.1 Ma).

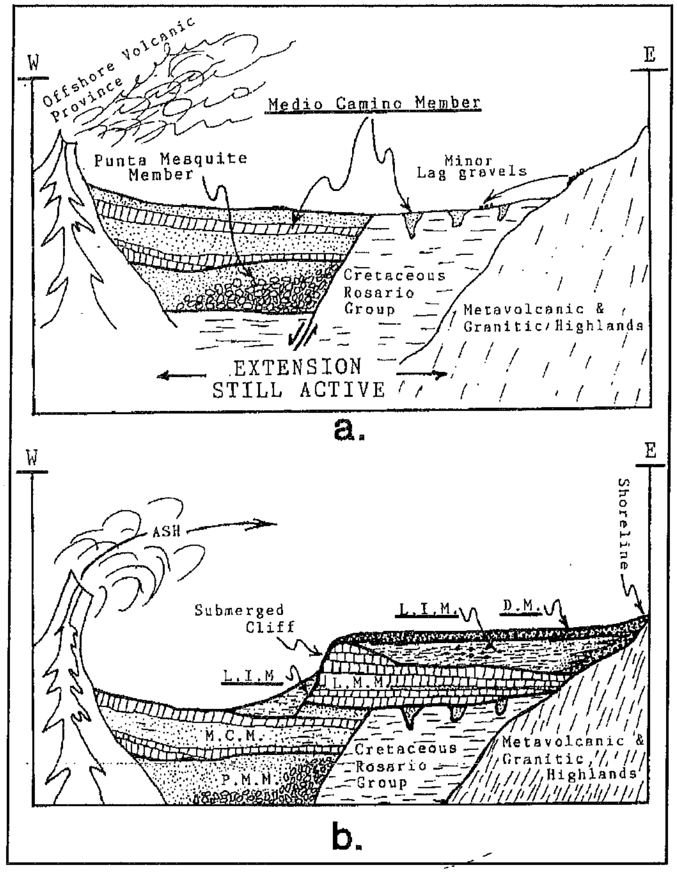


Figure 15

a.) Schematic cross section of the coastline during the deposition of the Medio Camino Member of the Rosarito Beach Formation, ?Zemorrian - Relizian (?23-16.1 Ma), see Figure 14. b.) Schematic cross section of the La Mision area during deposition of the Los Indios Member (L.I.M.) and Descanso Member (D.M.) of the Rosarito Beach Formation. Fossils collected from the Los Indios Member have indicated correlation with the Relizian?/Luisian benthonic foraminiferal stages, the Temblor molluscan stage, and the (?)Hemingfordian/(?)Barstovian land mammal stages (Demere and others, 1984). P.M.M. = Punta Mesquite Member, M.C.M = Medio Camino Member, L.M.M. = La Mision Member (modified from Ashby, 1989).

surfaces of some flows exhibit pahoehoe character suggesting subaerial deposition. Flow directions measured on these surfaces also suggest an east-northeast paleo-flow direction. The scoriaceous character throughout the basalt suggests that this area was near the terminus of a basalt flow. To the northeast, these basalts are thinner (1.8-4.6m) and clearly abut (lap out against) the Cretaceous sedimentary rocks. This lapout is visible below the cemetery at Arroyo Descanso (approximately 3km north of Medio Camino) where several thin basalt flows overlie the Cretaceous mudstones.

Upper Tuff

At one locality in the northern part of the area, just east of the cemetery at Arroyo Descanso, (3km north of Medio Camino) a 7 meter tuffaceous unit overlies the upper basalt flow of the Medio Camino Member. This tuffaceous unit is in turn overlain by the basal basalts of the La Mision Member. Therefore it is probable that the Medio Camino Member once contained a thick tuffaceous unit that was deposited between the upper basalt and the overlying La Mision Member that has been subsequently eroded away (Figure 12). This poorly exposed tuff unit is included in the Medio Camino Member. In general, however, the top of the Medio Camino Member is covered by Pleistocene terrace deposits and Quarternary alluvium.

Discussion

The Medio Camino Member is affected by the broad warping and faulting that disturbs the underlying Punta Mesquite Member at Punta Mesquite. A north-trending fault with normal throw, down to the west, is present at Punta Mesquite and is readily traceable north until it is covered by Quaternary alluvium and Pleistocene terrace deposits 0.5km north. At the road cut below the cemetery, a fault with normal throw (down to the west) was also noted to have affected the Medio Camino basalts, and appears to have offset the overlying Pleistocene terrace. At the Medio Camino locality, a normal (down to the east), perhaps oblique-slip fault is present in the sea cliffs.

The age of these basalts is still unknown, although potassium-argon determination is underway. The middle tuff bed was sampled for microfossils but none were obtained. The Medio Camino Member is overlain by the La Mision Member basalt, which has been dated at 16.1±2.1Ma (Gastil et. al., 1975).

Conclusion

The upper portion of the Punta Mesquite Member records increasing volcanism characterized by lithic crystal lapilli tuffs in the upper part. More intense volcanism followed during deposition of the Medio Camino Member which infilled existing paleotopographic lows by tuffs, creating a relatively flat surface, upon which basalts were later deposited (Minch et. al., 1984; Ashby and Minch, 1988; Ashby, 1989).

Initiation of volcanic eruption from an offshore (west of present coastline) volcanic province in the Medio Camino area deposited extensive tholeiitic basalts (Hawkins, 1970), which spread eastward to abut (lap out against) the Middle Miocene sea cliffs which were composed of Cretaceous sediments of the Rosario Formation (Figures 14 and 15a). These basalts spread north and south from what appears to be the center of north-south distribution at Punta Mesquite; where the basalts and tuffs of the Medio Camino Member are thickest. The Middle Miocene sea cliff was probably controlled by a fault scarp, suggested by the abrupt termination of basalt flows in the Medio Camino Member of the Rosarito Beach Formation and by syndepositional faulting to the south of Punta Mesquite (Ashby, 1989).

Continued volcanic activity originating from an offshore (west of the present coast line) volcanic province deposited ash in the eastern portion of the basin, at levels above the Middle Miocene sea cliffs. These tuffs also filled rills and small canyons cut into the underlying Cretaceous rocks. Volcanic deposition continued progressively filling up the basin (working its way up the sea cliff), to finally overstep it, allowing basalt to flow east until it abutted the foothill belt of the Peninsular Ranges batholith. This configuration formed an extensive eastward sloping, subaerial basaltic platform upon which is recorded the subsequent marine transgression and subsequent regression of the Los Indios and Descanso Members of the Rosarito Beach Formation during the Luisian (Figure 15b).

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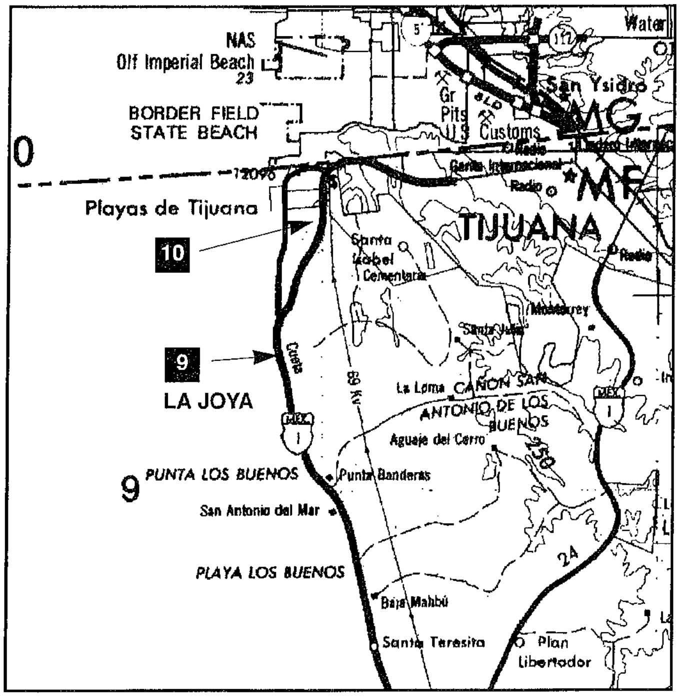

Continue north along the coast to the La Joya turnoff.

Field Trip Stop #9

La Joya

Upper Pliocene Stratigraphy and Paleoecology of the San Diego Formation

Speakers: James R. Ashby & John A. Minch

Well exposed units of the Upper Pliocene San Diego Formation and an underlying member of the Middle Miocene Rosarito Beach Formation will be examined in this area. The exposures are best viewed by crossing the bridge, passing through the gate and walking up the sewage treatment plant access road into a small road cut to the north.

Previous geologic work in this area was conducted by Minch (1967) who mapped the area and described the stratigraphy and structure of Miocene and Pliocene rocks. Rowland (1972) collected fossils and described the paleoecology from fourteen localities in this area, and Ashby and Minch (1984) made site specific examinations, important faunal additions, and measured the section at this location (see Figure 16).

Stratigraphy

The La Joya section exposes the upper tuff bed and upper basaltic flow unit of the Middle Miocene Costa Azul Member of the Rosarito Beach Formation (exposed at the bridge level). Unconformably overlying these sediments and deposited onto a westerly dipping monocline are the Upper Pliocene sediments of the San Diego Formation. Lithologic descriptions of these rocks can be found in Figure 16. Examination of the upper part of the basalt in the Costa Azul Member of the Rosarito Beach Formation yields spheroidal shaped structures within the flow unit. These have been referred to by other workers in the area as pillow-like structures ranging from 5 - 40 cm. in diameter. However, upon closer examination of the outcrops at this locality and at others in the area, it is clear that the structures are not pillows at all, rather a product of spheroidally weathered blocks controlled by a set of closely spaced horizontal and vertical joints. Therefore, this basalt was most likely not deposited in a marine environment.

Paleoecology

Fossils were collected from two localities in the San Diego Formation here and are listed in Table 1. Rowland's (1972) locality A-240 is the same as San Diego Museum of Natural History (SDMNH) 3253. Located in a small road cut approximately 100 meters up the road to the left of the guard shack. Locality SDMNH 3254 is 60 feet higher in the section.

The fauna collected from locality SDMNH 3253 and 3254 are each indicative of two nearshore paleoenvironments. Rowland (1972) first recognized these two paleoenvironmental components at his locality A-240 (SDMNH 3253), Ashby and Minch (1984) found these components consistent with some additions and clarifications (Table 1).

SDMNH 3253 contains two littoral to sub-littoral invertebrate faunal groups: an epifaunal assemblage which existed in close proximity to a rocky area characterized by Acanthinia, Balanus, Calliostoma, Cantharus, Olivella, Polinicies, Tegula, Thais, and Turritella; and an infaunal group indicative of a moderately protected area with a fine sandy to silty substrate characterized by Acilia, Anadara, Calyptraea, Chione, Chlamys, Dosinia, Prototheca, Siliqua, and Spisula, dominated by well preserved Patinopecten healyi. This bifaunal assemblage is consistent with the conglomeratic and sandy interbeds of the basal unit. Vertebrates present at this locality consist of Carcharodon, Isurus, Carcharhinus, Myliobatis, dolphin and whale remains. The faunal assemblage and lithostratigraphy suggest that these sediments accumulated just offshore as a death assemblage

GENERALIZED STRATIGRAPHY NEAR LA JOYA

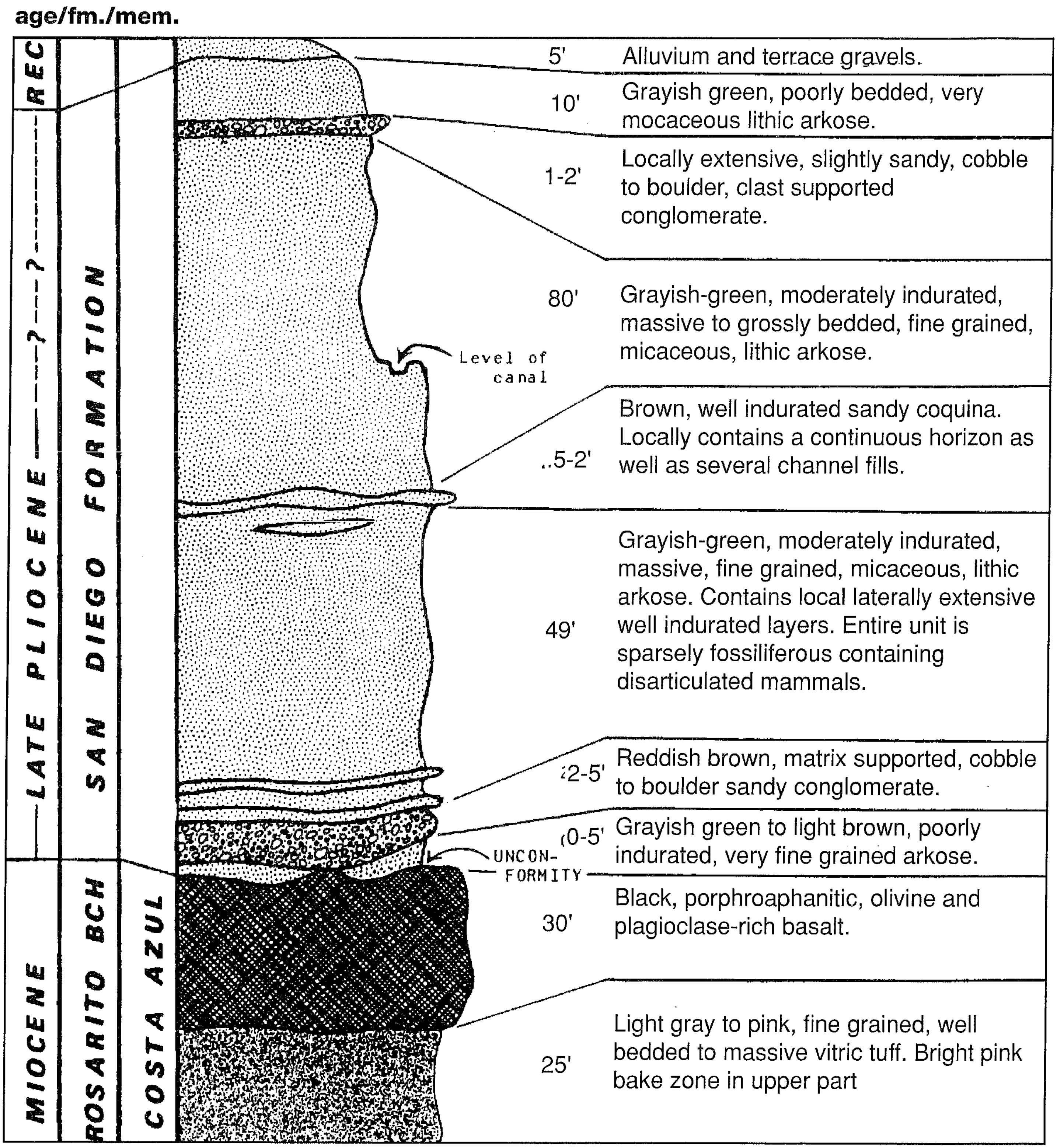

Figure 16 *Measured section at La Joya, from Ashby and Minch, 1984.*

receiving sediments and entrained biodetritus from the two aforementioned invertebrate paleoenvironments, and the presence of deeper water organisms such as large sharks, whale, and dolphin. The Patiuopectin population established itself after the transportation and deposition of the rest of the fossil molluscan material.

Notable in the fauna at this locality is the extinct great white shark Carchardon megalodon Agassiz for which the literature seems to favor a Miocene range. A well preserved dentary serves to document the presence of this shark in the Upper Pliocene San Diego Formation.

SDMNH 3254 located 60 feet higher in the section also contains fossils indicative of an offshore death assemblage containing a minor littoral to sub-littoral faunal component. The locality is dominated by well preserved specimens of the coral Paracyathus stearnsii Verrill which is presently found at depths greater than seventy feet, most abundantly below ninety feet. Cyclocardia, Lucina, and abundant Dosinia comprise the majority of the molluscan fauna and indicate a subtidal to offshore environment. A subtidal influx is also suggested by the presence of Cancellaria, Cantharus, Polinices, and Ostrea.

This invertebrate assemblage suggests a deeper water paleoenvironment than that at SDMNH 3253 and probably accumulated, aided by storm activity which carried the intertidal and shallower water fauna out into an offshore environment. SDMNH 3254 likely represents a seward facies of SDMNH 3253. These sediments were deposited as sea level transgressed this area during the Late Pliocene. Abundant channel scours and fills in the upper part of the section seem to support this hypothesis.

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TABLE 1 - Faunal List, La Joya, Baja California, Mexico

	Locality 3253	SDMNH 3254
GASTROPODA		
Acanthinia emersoni Hertlein and Allison	X	
Calliostoma kerri Arnold	X	
Calyptraea mammillaris Broderip	X	
Cancellaria cf. C. tritonidea Gabb	X	
Cerithidea californica Haldeman	X	
Crepidula princeps Conrad		X
Megasurcula carpenteriana Gabb		X
Muricidae indet.		X
Nucella lamellosa Gmelin	X	X
Nuculana taphria Gmelin		X
Olivella biplicata Sowerby	X	
Ophiodermella graciosana (Arnold)	X	
Polinicies reclusianus Deshayes	X	X
Tegula funebralis A. Adams	X	
Tegula gallina (Forbes)	X	
Thais emarginata Deshayes	X	
Thais cf. T. transcosana Arnold		X
Thais sp?		X
?Turbo	X	
Turritella cooperi Carpenter	X	X
PELECYPODA		
Acila castrensis Hinds	X	
Anadara trilineata Conrad	X	
Chione elesmerensis English	X	
Chione kanakoffi Hertlein and Grant		X
Chlamys parmeleei Dall	X	
Cyclocardia ventricostata Gould		X
Dosinia aff. *ponderosa* n.sp. Gray	X	X
Lucina nuttalli Conrad		X
Lucinoma annulata Reeve	X	
Macoma nasuta kelseyi Dall		X
Mactra sp?	X	
Ostrea erici Hertlein		X
Patinopecten healyi Arnold	X	
Protothaca tenerrima Carpenter	X	
Saccella taphria Dall	X	
Siliqua lucida Conrad	X	
Spisula hemphilli Dall	X	
Thyasira bisecta Conrad	X	
Tivela stultorum Mawe	X	
VERTEBRATA		
Carcaradon megalodon Agassiz	X	
Carcaradon sulcidens Agassiz	X	X
Carcharhinus sp?	X	
Dolphin bones	X	
Isurus plana	X	
Mylobatoidea *Myliobatis sp?*	X	
Whale bones	X	
COELENTERATA		
Paracyathus stearnsii Verrill	X	
ARTHROPODA		
Balanus sp?	X	
Crab claws	X	

Return to Mexican Highway 1 and head north.

Field Trip Stop #10

Tijuana

Fault Zone Between the Coronado Bank and San Miguel-Vallecitos-Calabasas Faults

Speaker: John A. Minch

The area between the two lineaments has revealed evidence suggesting a continuation of the two lineaments. This evidence consists of several shear zones. The shears bear evidence of strike-slip and oblique separation, and suggest strike-slip separation of Pliocene beds up to 10 kilometers. The entire fault zone would be approximately 300 kilometers in length and pass within 10 to 20 kilometers of downtown San Diego. The maximum credible earthquake for the fault would be about 7.5 Richter Magnitude with a maximum probable earthquake of at least 6.7 Richter Magnitude. Peak horizontal bedrock accelerations in downtown San Diego from a maximum probable earthquake could exceed 0.5 g. If the zone proves to be present this fault zone controls the Rose Canyon and other secondary faults within San Diego (Artim et. al., 1989).

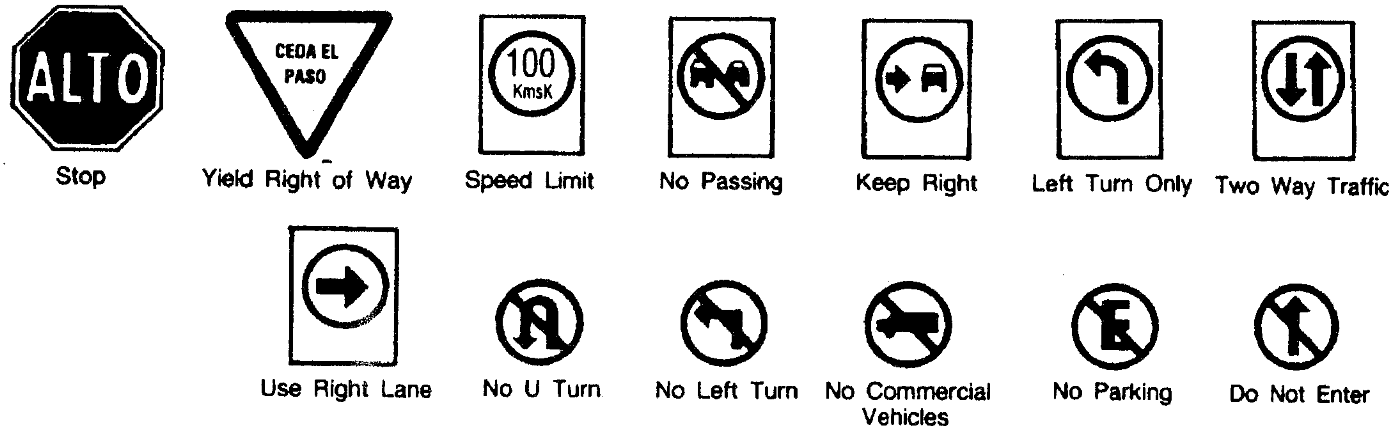
Field Trip Stop #10 concludes our San Diego Association of Geologists 1989 field trip. From Stop #10, travel north then west on Mexican Highway 1 to reach the border crossing. Return north to San Diego, California. The field trip leaders and SDAG executive committee hope this trip has been enjoyable and informative.

GLOSSARY

Bahiá	Bay
Cuesta	Slope, Hill
Cueva, Gruta	Cave
Cumbre	Summit
Cerro	Hill
Cerveza	Beer
Embalse	Reservoir, Man-Made Lake
Geológico	Geological
Falla	Fault
Lago	Lake
Laguna	Lagoon, Lake
Llano	Plain
Mar	Sea
Mirador	Viewpoint
Pantano	Swamp
Playa	Beach
Puerto	Port, Harbor, Pass
Punta	Point, Headland
Ría	Tidal Estuary of a River
Roca	Rock
Sierra	Mountain Range
Taberna, Cantina	Bar, Tavern
Torrente	Mountain Stream
Norte	North
Sur	South
Este	East
Oeste	West

Mexican Traffic Signs

REGULATORY



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