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GEOLOGIC HAZARDS EVALUATION

OF THE

CITY OF SANTA BARBARA

October 27, 1978

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TABLE OF CONTENTS

City of Santa Barbara
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LIST OF PLATES

* Oversize Plate that accompanies report

** Plate included in report

LIST OF TABLES AND FIGURES

Tables and Figures are included in report.

October 27, 1978

City of Santa Barbara
Division of Land Use Control
620 Laguna Street
Santa Barbara, California 93101

Subject: Geologic Hazards Evaluation of the City of Santa Barbara

Gentlemen:

INTRODUCTION

The City of Santa Barbara exists in a complex geologic region that contains a significant number of potential geologic hazards. This investigation is intended to identify, locate, and evaluate these geologic hazards, thus assisting land planners and engineers in planning future projects so as to minimize risks to human life. In addition, this study can be used by interested citizens to evaluate sites of particular interest.

SCOPE OF WORK

In conformance with our Proposal dated April 20, 1977, and the agreement of services dated July 20, 1977, this office has evaluated the following geologic hazards:

(1). Ground shaking (seismic-induced)
(2). Fault location - ground rupture
(3). Landslide (location) and slope stability

(4). Liquefaction

(5). High ground water

(6). Compressible/collapsible soils

(7). Soil Creep

(8). Erosion/seacliff stability

The occurence of these hazards, and an evaluation of their significance are presented on the Plates accompanying this report. The base map used to show most hazards is a 1978 aerial photograph (1" = 1000' scale). For slope-dependent hazards, a 1" = 1000' scale topographic map has been used. Interrelated hazards such as high ground water and liquefaction are presented together. The seacliff stability maps are on a 1" = 600' scale in order to provide more detail. In addition to the hazard maps, a separate geologic map is included.

INVESTIGATION

Geologic Map

Introduction

Since all the geologic hazards investigated reflect soil or rock type (lithology), the first phase of this study necessarily involved preparation of a geologic map (Plate 1). Other geologic maps of the City of Santa Barbara have been made (Dibblee, 1966; Muir, 1958; Upson, 1951; and Herron, 1975), but none provides the detail required by this study. New exposures of faults in geologic exploratory trenches and road cuts enabled this investigation to be more detailed than earlier studies.

Lithology

The rock units shown on Plate 1 are generally the same as those described by Dibblee (1966), although an additional unit (older alluvium) has been mapped. Plate 1 contains a short description of each rock unit. For more detailed descriptions, the reader is referred to Dibblee (1966).

Faults

A significant number of previously unmapped faults located primarily in the Mission Ridge - Sycamore Canyon area were observed during the study. These faults are too numerous to describe individually, but are shown on the geologic map. Major faults are described below and located on Plate 1.

Mesa Fault

The Mesa Fault forms the uplifted "La Mesa" between the harbor and Arroyo Burro Creek. The fault generally parallels Modoc and San Andres Roads. The fault is not clearly exposed; however, its location has been inferred, on the basis of water well data and rock exposures in the western portion of the city. In the southern downtown area, the fault location is inferred on the basis of possible fault line features that include recurrent sidewalk and street damage, historic hot springs, reported railroad track displacement, and small anomalous topographic mounds or possible scarps.

The Mesa Fault can be traced southeastward from its intersection with the More Ranch and Mission Ridge faults for about four miles. It is inferred that the fault extends into the sea slightly south of Stern's Wharf, near the Veterans Hall. At this location the railroad tracks were reportedly severed during the 1925 earthquake (P. Olsen, personal communication, 1978). Recent investigations (Muir, personal communication, 1978) indicate that the Mesa Fault joins the Offshore Barrier Fault (Muir, 1968), and eventually joins the Rincon Creek Fault in Carpinteria.

There is no conclusive evidence that the Mesa Fault is active. Professor A.G. Sylvester of the University of California, Santa Barbara, has established a series of precise level lines across the fault. The level line data indicate no vertical movement or creep has occurred in the past eight years (A.G. Sylvester, personal communication, 1978). Unfortunately the fault has not been exposed in exploratory trenches, so it cannot be demonstrated that Holocene soils have been offset by the fault. Overall, the Mesa Fault is considered potentially active, exhibiting some characteristics of activity such as curb push-outs, possible railroad track displacement, and so on.

No seismic events have been instrumentally recorded on the Mesa Fault. The 1925, 1941, and 1978 earthquakes; however, occurred on an active offshore fault(s) (probably the Red Mountain and/or Pitas Point faults), and offshore geologic data suggest a structural relationship between the Red Mountain fault and the Mesa/Rincon Creek Fault (Geotechnical Consultants, 1974a). The Mesa Fault is therefore considered Capable according to Atomic Energy Commission standards. Future movement of the Mesa Fault is expected to be sympathetically related to a major event on the Red Mountain Thrust, rather than generated from the Mesa Fault itself.

Mission Ridge Fault

The Mission Ridge Fault trends east-west across the northern portion of the City. The fault forms a series of hills including those east of Sycamore Canyon, the north side of Mission Ridge, and the small mesa south of State Street between De La Vina Street and Hitchcock Way.

Although not well exposed the eastern extension of the fault is believed to join the Arroyo Parida Fault in Montecito. The western portion is covered by alluvium. It is uncertain whether the Mission Ridge terminates at the juncture of the Mesa-More Ranch-Mission Ranch Fault or is continuous as the More Ranch Fault.

No seismic events are instrumentally attributable to the Mission Ridge Fault. Trenching across a branch of the fault demonstrated that it was active during or after the late Pleistocene (last 500,000 years) but did not demonstrate any Holocene movement (last 11,000 years). Trenches across the Arroyo Parida Fault (an extension of the Mission Ridge Fault) indicate late Pleistocene movement. Holocene movement may have occurred, but cannot be determined without more sophisticated dating of trench samples. The Mission Ridge Fault is considered potentially active, however, additional investigations are recommended along the eastern extent to determine if this portion of the fault is more active.

Lavigia Fault

The Lavigia Fault can be traced interruptedly across the City for approximately 3.5 miles. It emerges in the Hope Ranch area, crosses the Mesa, and extends out to sea near Santa Barbara Point. The fault is overlain by terrace deposits from La Vista del Oceano to the sea-cliff; its location here has been determined by subsurface data (Herron, 1975).

Based on seacliff exposures near the point, the Lavigia Fault is inferred to dip to the southwest at 75° or steeper. This may not be the main trace of the fault, but exposures to the north do not adequately delineate any others.

The best evidence of displacement on the Lavigia is near Veronica Springs. Here Miocene shales are upthrown on the south side of the fault and a sequence of Pliocene-Pleistocene Santa Barbara Formation is down-thrown on the north. Water well data in this area indicate minimum vertical displacement of 600 feet. This displacement may attenuate toward the east, where the strain may be absorbed by the numerous folds from Arroyo Burro to Santa Barbara Point. The Lavigia Fault is considered potentially active since it displaces Plio-Pleistocene sediments.

Lagoon Fault

The Lagoon Fault lies at the base of the south-facing hill between the Montecito County Club and Sycamore Canyon. This east-west trending fault displaces Miocene shale on the north against Pleistocene fanglomerate to the south. An exploratory trench at the north end of Lou Dillon Lane exposed the Monterey Shale in fault contact with the fanglomerate (R. Courdray, personal communication, 1978). The fault is reported to dip to the south at approximately 60° (T.L. Bailey, writter communication, 1977). The Lagoon Fault is considered potentially active since it displaces late Pleistocene fanglomerate.

Sycamore Fault

The Sycamore Fault can be traced nearly three miles, from approximately 4500 feet east of Sycamore Canyon where it may intersect the Montecito Fault, to Mountain Drive where it is apparently truncated by the Mission Ridge Fault. Although investigators have mapped the Sycamore Fault northwestward through the San Roque district (Herron, 1974), this study revealed no conclusive evidence that the fault extends west of Mountain Drive.

The south-dipping, south side down Sycamore Fault juxtaposes Miocene Monterey Shale with Pleistocene fanglomerate on the south side of Mission Ridge. The fault can be traced as a formational contact across the south side of Mission Ridge and is well exposed on Mission Ridge Road in the Franceschi area. Springs on Tremonto Road near Mountain Drive mark the apparent trace of the fault where it intersects the Mission Ridge Fault.

The Sycamore Fault is considered potentially active since it offsets late Pleistocene fanglomerate.

Montecito Fault

The Montecito Fault was first mapped in 1933 by Bailey. He called it the Eucalyptus Hill Fault, it was mapped generally as shown on Plate 1. An eastward extension of the fault was first suggested by Geotechnical Consultants, Inc. in 1974, and the entire fault was renamed the Montecito Fault. Recent geologic investigations in eastern

Santa Barbara indicate a fault system with the same alignment as the Montecito Fault. As a result, we have extended the Montecito Fault northwest of Bailey's mapping.

The Montecito Fault system is most evident on Chase Drive, where Miocene Monterey Shale is exposed north of the fault and Pleistocene fanglomerate to the south. Fault plane attitudes indicate a slight south dip to 85°.

The fault can be traced inside the City for approximately 2.2 miles, apparently terminating against the Mission Ridge Fault atop Mission Ridge. The length of the fault is approximately 6 miles, with the eastern trace terminating against the Arroyo Parida Fault east of Montecito.

The Montecito Fault is considered potentially active since it offsets late Pleistocene fanglomerate, Moreover, exploratory trenches along a small branch fault of the Montecito or Sycamore fault suggest even more recent movement. Additional trenching and dating are recommended to further evaluate this fault's activity.

Eucalyptus Hill Fault

The Eucalyptus Hill Fault can be traced for approximately 1.5 miles within the northeast corner of the City, where it extends from Montecito under the deep alluvial cover along Camino Vieja. The fault is exposed in the hillsides on either side of Barker Pass Road. Exploratory trenches on both sides of the road exposed two possible branches of the fault (D. Weaver and R. Courdray, personal commumication, 1978). The southern branch apparently turns northwest and crosses

Sycamore Canyon near Ranchito Road.

Total displacement on the fault is unknown, although water well data (near Woodley and Sycamore roads) indicated a minimum vertical displacement of approximately 400 feet. The youngest rocks known to be displaced are Pleistocene fanglomerates. The fault is therefore considered potentially active.

Summary

None of the faults observed during this investigation are demonstrably active. By definition active faults have surface displacement within the past 11,000 years (California Division of Mines and Geology). As mentioned above, the Mesa Fault exhibits some characteristics of an active fault (fault line fractures and tectonic relationship to active offshore faults); it is therefore considered a capable fault. Additional field investigation of the three major faults crossing the city (Mesa, Mission Ridge, and Lavigia) is strongly recommended, to determine their activity more precisely. Until comprehensive field investigations are completed, individual field studies are recommended for new structures proposed in all fault zones.

Use of Fault Map in Evaluating Existing Structures

Because of the poor field exposure of most faults and the relativley large scale of the base map, the fault map should not be used to determine whether a specific house is located on a fault. Site-specific field studies are necessary to determine the hazard to individual structures located in fault zones shown on Plate 1. As stated above, no faults in the City of Santa Barbara are considered active. In no case should a structure or structures be devauled or condemned on the basis of a fault shown on the geologic map.

Seismic Zonation

Seismic History

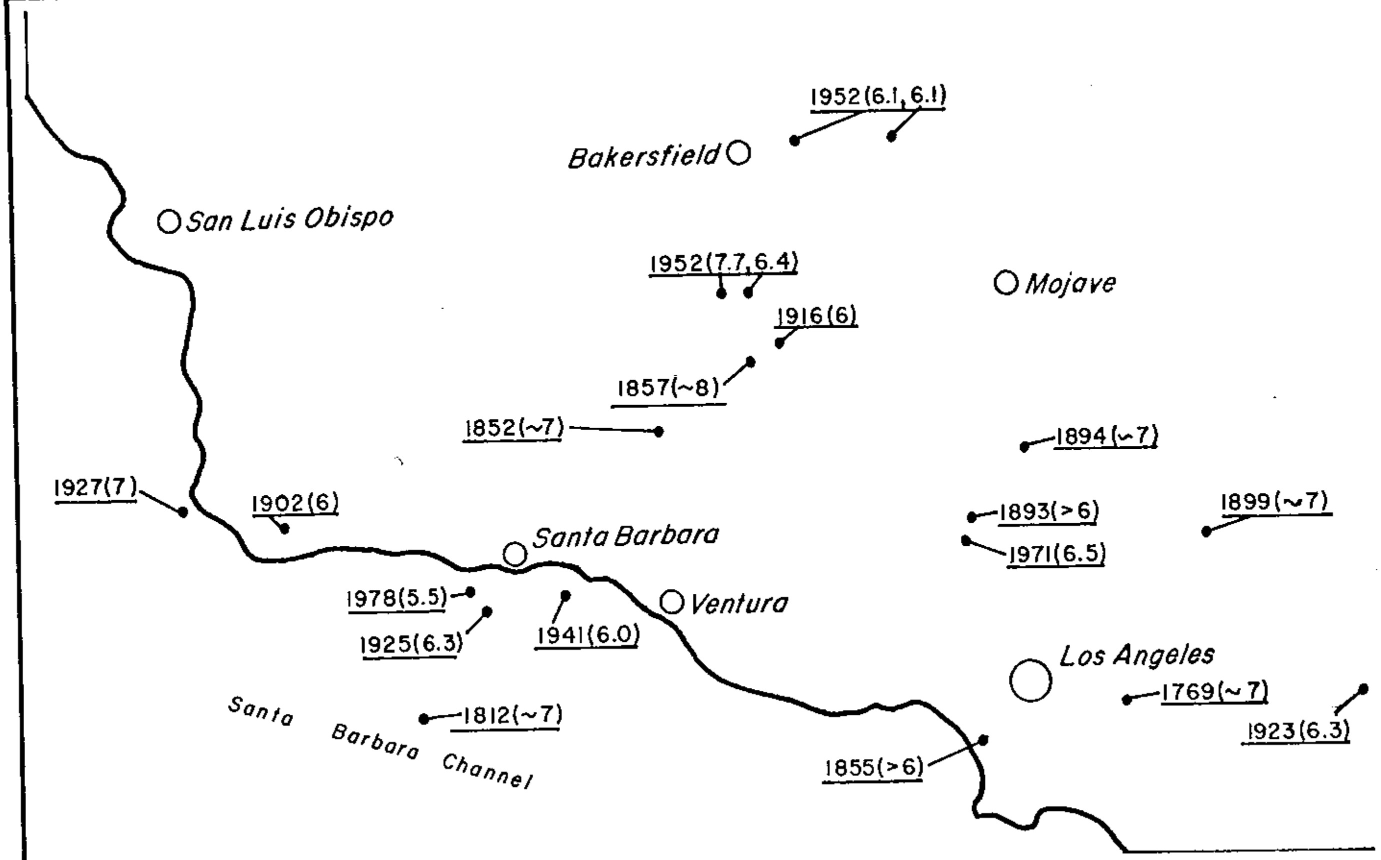
The Santa Barbara area has experienced several significant earthquakes since the first European settlement: 1925 (Mag. 6.3), 1941 (Mag 6), and 1978 (Mag 5.5-5.7) (Plate 2). These events and their aftershocks sequences all occured offshore. The causative fault has not been positively identified; the Red Mountain Thrust or an extension of the Pitas Point Fault was probably responsible for these events.

Much larger events (although more distant geographically) occurred in 1812 (Mag 7+) and 1857 (Mag 8+). The 1812 event probably orginated in the central Santa Barbara channel, but due to its offshore location and the the lack of population and structures the epicenter cannot be precisely established. The 1857 event was the Fort Tejon earthquake on the San Andreas Fault. This is perhaps the largest earthquake to have occurred in southern California in historic times, although Sieh (1978) has shown that the southern San Andreas Fault has undergone several earthquakes of this general magnitude in the past millineum.

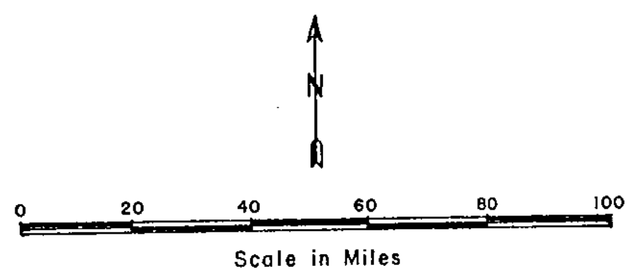
Seismotectonics

An evaluation of the active and potentially active faults in the Santa Barbara region provides a basis for assessing future seismic

File 142-001



MAJOR HISTORICAL EARTHQUAKES IN THE SANTA BARBARA REGION



PRE 1933 LOCATIONS AND MAGNITUDES HAVE BEEN ESTIMATED FROM HISTORICAL RECORDS AND ACCOUNTS

REFERENCE: Allen et al., 1965;
Goffman and von Hake, 1973

By K. Frost Date 10-18-78

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Plate 2

events. The largest earthquake that could be expected on an active or potentially active fault may be determined empirically by using total fault length (Greensfelder, 1973). Based on the work of Albee and Smith (1966) and Bonilla and Buchanan (1971), the maximum credible earthquake is defined as the event that would occur if 50% of the fault length ruptured. A more realistic design earthquake, one with a greater degree of recurrence, assumes that 25% of the fault length would rupture. The magnitude of possible seismic events on faults in the Santa Barbara area is given in Table I.

Because of their proximity to the City, the most critical faults in the Santa Barbara area are those that pass through or near the city itself: the Mission Ridge, the Lavigia, the Mesa, the More Ranch, and the offshore Red Mountain Thrust. Earthquakes on larger more distant faults would attenuate (lose energy) by the time they reached Santa Barbara and thus are not controlling events.

Determination of seismic potential on the local faults is related to regional tectonics. The Mesa and Lavigia faults are reportedly secondary faults that converge at depth with the active Red Mountain Thrust, an offshore north-dipping fault. Thus the Mesa and Lavigia may not have the capacity to generate an earthquake, but would provide conduits for seismic energy generated from the Red Mountain Thrust (causative fault). This type of fault movement is termed sympathetic rather than generative. Thus, the Red Mountain Thrust is a more significant fault than the onshore Mesa or Lavigia faults. An additional complication is that the Mission Ridge and More Ranch faults may be connected to a more extensive series of related faults. Further work is required to determine the activity and significance on the Mission Ridge/Arroyo Parida and the More Ranch faults. For our analysis, the

Estimated Magnitude of Future Earthquakes

Occuring on Significant Faults

Table I

Fault Name	Length* (miles)	Distance from * S.B. Area (miles)	Magnitude of Maximum Credible Event (50% rupture)	Magnitude of Design Earthquake (25% rupture)
Big Pine	53+	15	7½ **	6.5
Lavigia	9.5	0	5.9	5.4
Mesa/Rincon Creek	14.5	0	6.2	5.7
Mission Ridge-Arroyo Parida	21+	0	6.5+	5.8+
More Ranch	30	0 to 8	6.8	6.0
Pitas Point	8+	25-	5.8+	5.2+
Red Mountain	40+	6+	7.0	6.3
Santa Ynez	80+	8	7½ **	6.6+
San Andreas	620	40	8¼ **	n/a

* Lengths of faults assumes that new fault begins at major juncture. Imprecise location of offshore faults precludes exact determination of distance to the City of Santa Barbara.

** Greensfelder, 1973

Note: This method of analysis assumes that the fault in question be considered active. As discussed in the text, this has not been substantiated for all faults listed. Since all faults are at least potentially active, however, siesmic analysis is made for each.

the Mission Ridge is considered connected to the Arroyo Parida for 21 miles. The More Ranch is thought to be en echelon with the Red Mountain and extending to Gaviota. The More Ranch fault may be capable of generating a seismic event, but it is not as long as the Red Mountain; thus the Red Mountain is used in constructing a design earthquake.

Seismic Risk

A statistical study of earthquake hazards, was prepared in connection with a wastewater treatment plant (Geotechnical Consultants, 1974a). This study concluded that a 1% probability exists that a seismic event with an acceleration of 0.25g (peak horizontal acceleration) would occur in Santa Barbara in the next 75 years. The probability seems rather small considering the 1978 earthquake produced (uncorrected) values of about .2g. In all likelihood the 1925 earthquake produced ground motion of about .25g and the 1941 event generated 0.17g. We believe that a value of 0.25g should indeed be used, but that the recurrence interval is somewhat less than 75 years.

Seismic Zonation Assumptions

Good evidence exists that no appreciable attenuation of ground motion occurs within the near-field of an earthquake source (10km) (Hanks and Johnson, 1976; Donovan and Bornstein, 1975). Thus considering the uncertainity of the causative fault for any of the ground motions and the proximity of at least three sources to Santa Barbara, the entire City must be regarded as subject to the same levels of bedrock ground motion. Although there is greater probability of an offshore source, the Mission Ridge, More Ranch, and other faults should not be disregarded as potential causative faults.

Taking into consideration the earthquakes that could be associated with the faults of the Santa Barbara region (Table I) and attenuation studies, a design basis horizontal bedrock acceleration of 0.25g is proposed for the City. This motion could be generated from several sources including the Mission Ridge, More Ranch, or offshore faults. As indicated previously, however, it would probably reflect an event on the offshore faults.

The maximum credible or largest event that might be expected in the City would produce accelerations of about 0.5g (peak horizontal bedrock acceleration). Again, this could have several fault sources.

Seismic Zonation Methodology

Since the level of seismic ground motion at bedrock is assumed to be constant throughout the City, zonation of the City becomes a matter of variations in that motion because of site (soil) conditions. The effects of site conditions have been studied by Seed et al. (1975), Trifunac and Brady (1975), and Mohraz (1976). Based on these studies, the City of Santa Barbara has been divided into four site conditions:

(1) Bedrock
(2) Stiff Soil
(3) Thicker Alluvium
(4) Filled Estero

The following surface geologic criteria were used:

(1) Bedrock - all Tertiary rock except Rincon Formation

(2) Stiff Soil

  (a) Fanglomerate

  (b) Santa Barbara Formation

  (c) Terrace deposits

  (d) Alluvium less than 30 feet thick

  (e) Rincon Formation - because of thicker soil profile

(3) Thicker Alluvium
Greater than 30 feet thick - Recent and older alluvium

(4) Filled Estero
Based on Olsen (1972) and Herron (1975), filled esteros may be subject to subsurface movement, lurching, and liquefaction during seismic wave transmission.

Yet another zone is that immediately adjacent to a rupturing fault. Certain seismic wave phases generated by a surface-rupturing fault may transmit extremely high ground motions not assessed on normal attenuation curves.

Seismic Zones

The bedrock motion from local earthquakes is affected by the overburden, if any, between bedrock and the surface of the ground. In general, the thicker the column of overburden and less competent material, the greater the shift of the surface ground motion to lower frequencies. This shift has little affect on smaller structures (including single family dwellings), but does affect larger structures, which are more tuned to lower frequencies. Thus peak acceleration at the surface may diminish with thicker overburden, but the energy may be absorbed in lower frequency portions of the wave spectra.

Assessing the hazards for various types of structures is difficult because of the great variety of structures involved. Nevertheless three general catagories have been developed:

(1) Less than 4-story structures
(2) New large structures
(3) Old large structures

Under most conditions, the less than 4-story structures tend to survive quite well. The new larger structures refer to these built according to normal standards, but without any special design. Various engineering methods can alter the characteristics of buildings, however, so that these structures will survive as satisfactorily as smaller ones. The category of old large structures covers buildings erected by methods today considered sub-standard. These building may have been weakened by previous earthquakes and thus be more susceptible to damage than newer structures.

The possibility that greater hazards exist in some areas for larger structures suggests that new buildings in these areas should be given special consideration. This matter is addressed in the site period/building period formula adopted in the new Uniform Building Code. For major structures, however, dynamic analysis should be considered.

Table II gives some generalized figures for hazard levels. The areas in which these hazard levels exist are shown on Plate 3.

Seismic Hazard Levels

Table II

Design Earthquake

Bedrock Acceleration .25g Duration 20 sec.

	1-3 story	Larger*	Old Larger
Bedrock	Low	Low	Mod
Stiffer Soil	Low	Low-Mod	Mod
Thicker Alluvium	Low	Mod	Mod-High
Filled Estero**	Low-Mod	Mod	Mod-High

Maximum Credible Earthquake

Bedrock Acceleration .5g Duration 40-60 sec.

	1-3 story	Larger*	Old Larger
Bedrock	Mod	Mod	Mod-High
Stiffer Soil	Mod	Mod	High
Thicker Alluvium	Mod	Mod-High	High
Filled Estero**	Mod-High	High	Very High

* Normal Design - Specially designed buildings such as newer hospitals, would have lower hazard.

** Hazards in Filled Estero primarily reflect dynamics in subsurface soils rather than simple transmission of seismic waves.

It should be noted that these figures generally apply to earthquakes generated by local sources. Distant events, such as those on

Table II Con't.

the San Andreas Fault usually have lower frequencies of seismic energy. In the cases of the "Larger" and "Old Larger" categories this lower frequency would make bedrock behave much as the Stiffer Soil class.

Compressible/Collapsible Soils and Settlement Problems

Compressible and collapsible soils are loose, poorly compacted soils that usually occur in arid climates where rapid deposition is common. Soils deposited under these conditions settle or compress with time. A local soils engineer (Doral Neeley, personal communication, 1978) states that field densities in the Santa Barbara area are generally 80%-95% of maximum. On the basis of this information and our geologic mapping, we conclude that extensive areas of compressible or collapsible soils do not exist in the City of Santa Barbara.

There are, however, settlement problems in much of the downtown region of Santa Barbara that was once underlain by the old estero. Soils data generally indicate that consolidation is likely in these areas, primarily because of poor compaction of the fill emplaced after the 1925 earthquake. The approximate limit of the estero that existed prior to 1800 is shown on Plate 1. Soils investigations are recommended for structures located over the presettlement estero.

Liquefaction

Liquefaction is the loss of shear strength in soils during an earthquake. Soils most often affected are fine to medium grained, cohesionless sands in high water table environments. During an earthquake, the upward propagation of shear waves builds up excessive hydrostatic pressures. When the hydrostatic pressures equal the confining pressures, the sand will undergo large deformations (Seed, 1976).

Liquefaction occurs only if all the following parameters are present:

(1) Ground motion (cyclic shear stresses caused by an earthquake)
(2) High water table (generally less than 55 feet below ground surface)
(3) Sandy cohesionless soils
(4) Low relative densities (generally less than 72%)

The liquefaction potential in the City is shown on Plate 4. Areas where all of the above parameters probably exist are noted as areas of high liquefaction potential. Areas that may subsequently acquire high water tables, or support structures with heavy loads are considered conditionally liquefiable. Areas where soils or water well data have provided insufficient information are considered questionable.

A more detailed analysis of liquefaction can be approximated by using the standard penetration test (SPT). After a representative penetration resistance is measured in the field, the liquefaction potential can be evaluated with formulas developed be Seed (1976). Figure 1 presents a plot of liquefaction versus nonliquefaction soil conditions.

Because of the paucity of SPT data, our evaluation of liquefaction is somewhat generalized. Some information was available from Cal Trans on bridge and overpass projects, however. These data, as well as water well data, are presented on Plate 4. SPT data in old esteros and areas near the ocean support the high liquefaction potential zone shown on Plate 4.

We strongly recommend that a liquefaction evaluation be made for all new major or public structures located in the areas of high or

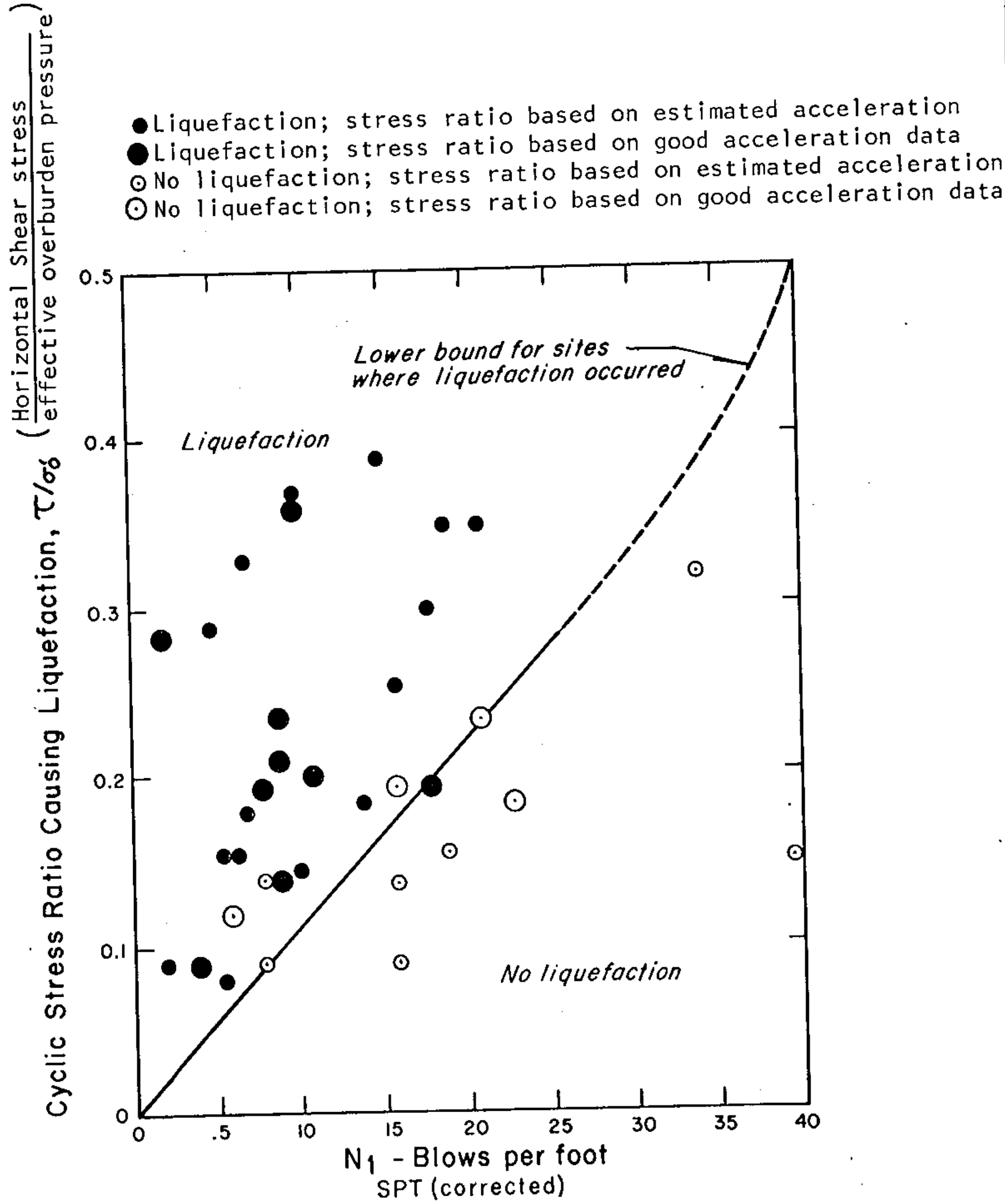

Figure 1. CORRELATION BETWEEN STRESS RATIO CAUSING LIQUEFACTION IN THE FIELD AND PENETRATION RESISTANCE OF SAND

(after Seed et al.)

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By K.Frost Date 10·18·78 File 142-001

conditional liquefaction potential shown on Plate 4.

Soil Creep - Landslides - Expansive Clay Soil

Soil creep is the slow downslope movement of expansive clay soils. Soil creep in areas of Santa Barbara are shown on Plate 5. Soil creep is generally divided into three categories.

(1) Active - Areas where downslope movement is reflected by topographic features (hummocky terrain), leaning trees, or structural damage.

(2) High Potential - Probable creep, but not as noticeable as in active areas. Generally soils are 5 to 25 feet thick, and highly expansive.

(3) Low to moderate - Areas with low probability of soil creep, except where soils are thick. Soils are generally 0 to 10 feet thick in these areas.

Evaluations by an engineering geologist or a soils engineer are recommended for all areas with high or active creep hazards.

Plate 5 also shows areas of expansive clay soils, which can be categorized as follows:

(1) Highly Expansive to Very Highly Expansive Clay Soil - these areas are usually related to the Rincon Formation and generally range in expansiveness from 12% to 45% (at 60 PSF* surcharge). Such expansiveness can damage unreinforced concrete

*PSF = Pounds per square foot

walls, patios, driveways, or house foundations.

(2) Moderately Highly Expansive Soil - These areas are generally related to the Monterey Formation. Expansiveness is usually 6% to 12% (at 60 PSF surcharge). This level of expansiveness can damage unreinforced (or nonengineered) patios, driveways, and retaining walls.

(3) Variable Soil Conditions - Soils in this area are quite diverse and ususally contain interlayered sandstone and clay soils (Sespe Formation), or shale and clay soil (Monterey Formation).

Areas of expansive clay are not particularly significant if proper soils investigations are conducted and the resulting recommendations are followed. Soils investigations are recommended for all structures in all areas with very highly expansive, moderately highly expansive, or variable soil conditions.

Included also on Plate 5 are landslides, which can be divided into two classes:

(1) Active - Slides that have apparently moved during historic time (Past 100 years). Movement is evaluated by the existence (or lack) of vegetation and fresh scarps, plus historic observations.

(2) Inactive - Slides that are discernible from morphology, but apparently have not been active during the past 100 years.

An engineering geologist's report is recommended prior to building on either active or inactive landslides.

Erosion

The portions of the City subject to rapid erosion are generally areas with steep terrain and unconsolidated sandy soils. The erosion hazard map (Plate 6) gives four categories of erosion:

(1) Active Erosion - Areas that undergo extensive active erosion during the winter and are characterized by active gullying and ongoing sedimentation. Actively eroding seacliffs and landslides are included in this category, as well as stream channels.

(2) High Erosion Potential - Steep areas, with slopes generally over 50%, that are likely to erode if vegetation is stripped and not replaced before rainy months. Generally included are soils forming over the unconsolidated sands of the Santa Barbara Formation, fanglomerate, Recent alluvium, and steep slopes in the Sespe Formation.

(3) Conditional Erosion Potential - Areas in which erosion may become more active if steep cut slopes are made. In general only minor maintenance problems exist at the present. These areas are lithologically similiar to category (2), but usua-lly occur on flatter slopes.

(4) Minimal Erosion Potential - Areas with insignificant rates of erosion.

Seacliff Stability

Plate 7 is a detailed geologic map of the seacliff area in the City of Santa Barbara. The stability of the seacliff depends on the geometric relationship between geologic structures (bedding planes, fold axes, and joints) and the bluff face.

Failures along the seacliffs, generally occur where bedding planes (rock layers) have been undercut by waves. When undercut, these layers become unsupported or "daylighted." Unfortunately the situation is exacerbated by the common occurrence of bentonite layers between bedding planes. Because it has extremely low resistance to shear when wet, bentonite lubricates rock layers, thus promoting large scale bedding plane failures.

To ascertain the stability of each rock slope along the bluff, a detailed program of borings and rock mechanics analyses would be required. By assuming, however, that unsupported bedding planes are unstable, that the average rate of seacliff retreat is 8 inches per year, and that the terrace deposits stabilize at a 2(H):1(V) slope, the following simplified setback formula can be developed:

$$\text{Setback} = \frac{\text{height of the shale seacliff}}{\text{Tangent of dip}} + (\text{thickness of terrace})(2)$$

(8"/yr)[1](75yrs)

This formula was used in establishing the Preliminary Setback Line shown on Plate 7. It should be emphasized that this line refers only to new construction with a design life of 75 years. Further, the line should be verified on a site-by-site basis, with sufficient boring

1 Norris, 1968

to determine the nature of subsurface geologic structures. The Preliminary Setback Line of Plate 7 does not apply to existing structures and should not be used to condemn or devalue existing structures.

RECOMMENDATIONS

To put the hazard maps in practical perspective, the following recommendations are made:

(1) Additional geologic studies should be performed on the Mesa, Mission Ridge, and Lavigia faults to determine whether these faults should be considered active and to define further the width of the fault zones. Until such studies are completed, individual studies prepared by an engineering geologist should be made for all new structures proposed on faults or in fault zones shown on Plate 1.

(2) A geologic investigation is recommended specifically for the vicinity of Sheffield Reservoir, to determine if a branch of the Mission Ridge Fault trends through the reservoir or its abutments.

(3) Soils investigations addressing settlement problems should be performed on all areas involving structures overlying the estero shown on Plate 1.

(4) Building - specific seismic investigations are recommended for all public buildings and structures larger than 3 stories in the filled esteros and thicker alluvium areas shown on Plate 3. Old large structures on thick alluvium and old esteros are a significant hazard to public safety. Because of variation in construction an individual evaluation of each building by a qualified team consisting of an engineering geologist, a geophysicist, and a structural engineer

conversant with earthquake dynamics is recommended.

(5) Liquefaction evaluations should be made for all new major or public structures located in high or conditional liquefaction potential areas shown on Plate 4.

(6) Investigations by an engineering geologist and a soils engineer should be performed for all structures proposed in areas of active or high potential soil creep, and for structures on active or inactive landslides.

(7) A soils engineer should conduct investigations for all structures proposed in areas of variable, moderate or highly expansive soils.

(8) Detailed grading plans with strict revegetation provisions should be required for all sites of proposed structures in areas of active erosion or high erosion potential. If cuts greater than 4 feet in height are proposed, the grading plan should consider erosion control in areas with a conditional erosion potential.

(9) New structures proposed on the seacliff should not be located within the Preliminary Setback Line shown on Plate 7 unless a site-specific investigation conducted by a certified engineering geologist indicated that the site appears stable for the design life of the structure.

We trust that the hazard maps accompanying this report and the recommendations given above are useful to you in evaluating new projects. If we can be of further assistance, please contact us.

Sincerely,

Michael F. Hoover
Certified Engineering Geologist
#977

Paul A. Sorensen
Project Geologist

Stephen Ryland - RN

Stephen Ryland
Project Geophysicist

ACKNOWLEDGEMENTS

We are grateful to Mr. Ray Coudray for the extensive geologic mapping and personal information that he contributed to this report. We are also grateful to Dr. Donald W. Weaver for contributing his knowledge of fault locations and general advice, Dr. Arthur Sylvester for his contribution on the Mesa Fault, and Mr. Phil Olsen for his contribution on the Mesa Fault and his review of our seismic zonation.

Important Note:

This investigation was performed for the City of Santa Barbara under contract signed in August 1978. The investigation is intended for use by the Division of Land Use Control as a guide in its evaluation of new projects. This investigation was not intended to satisfy the criteria established for a Seismic Safety Element and should not be used as such without additional studies and refinement. This study relied on existing data and field observations, as per contractural agreement.

The hazard maps presented should be used as guides in determining if additional studies are warranted for the evaluation of a new project. The scale of the base maps does not permit analysis of properties near hazard boundaries. Under no circumstances should this study be used to devalue or condemn property.

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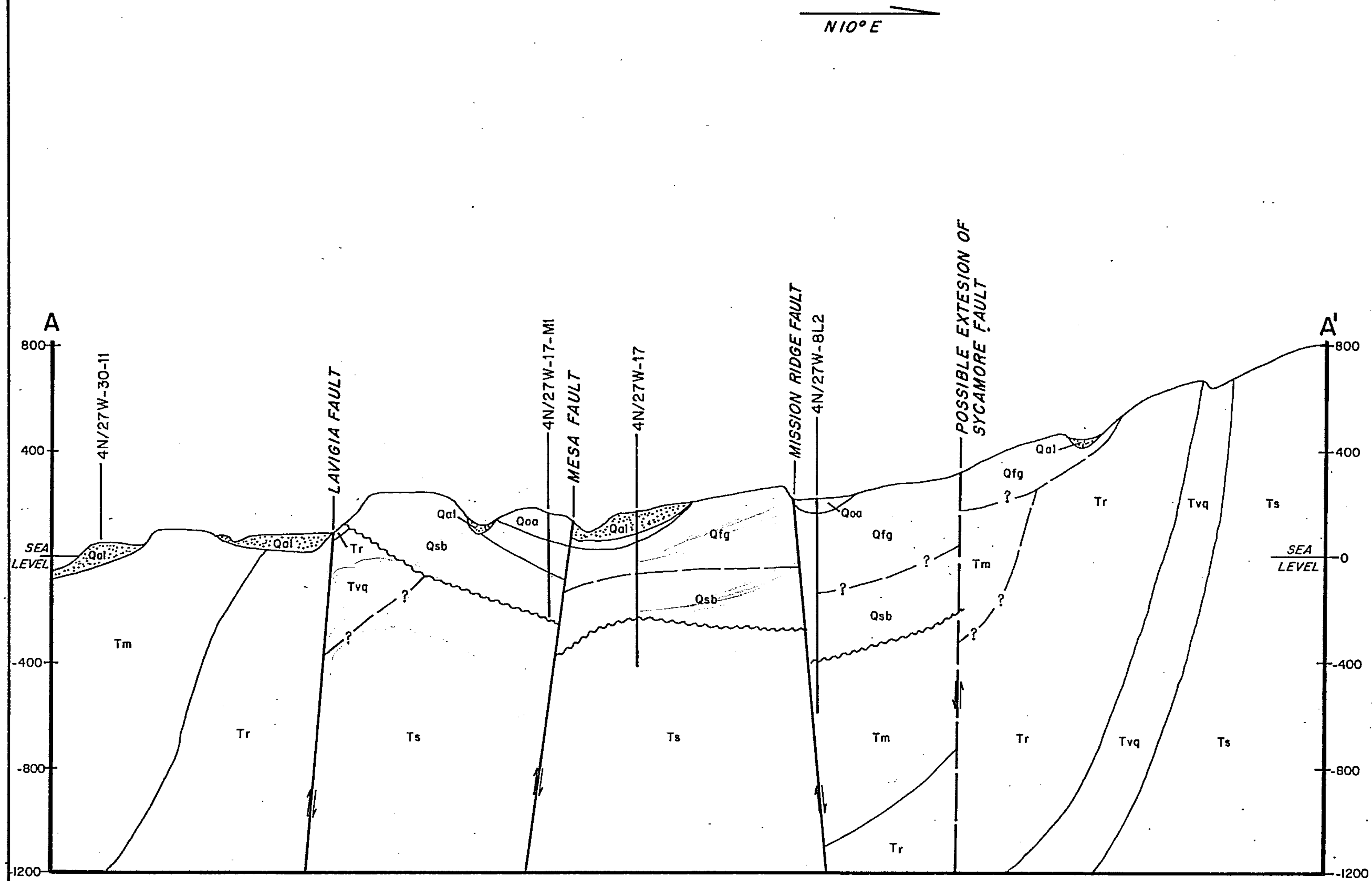
GEOLOGIC CROSS SECTIONS

and

COASTAL HAZARDS MAPS

(Plates 1a,b,c and Plate 7)



STRUCTURE CROSS SECTION ALONG LINE A-A'

KEY

QUATERNARY	Recent	Qal	Quaternary Alluvium
	Pleistocene	Qt	Terrace Deposit
		Qoa	Older Alluvium
		Qfg	Fanglomerate
TERTIARY	Pliocene	Qsb	Santa Barbara Formation
	Miocene	Tm	Monterey Formation
		Tr	Rincon Shale
		Tvq	Vaqueros Sandstone
	Oligocene	Ts	Sespe Formation

1" = 400'

vertical exaggeration x 5

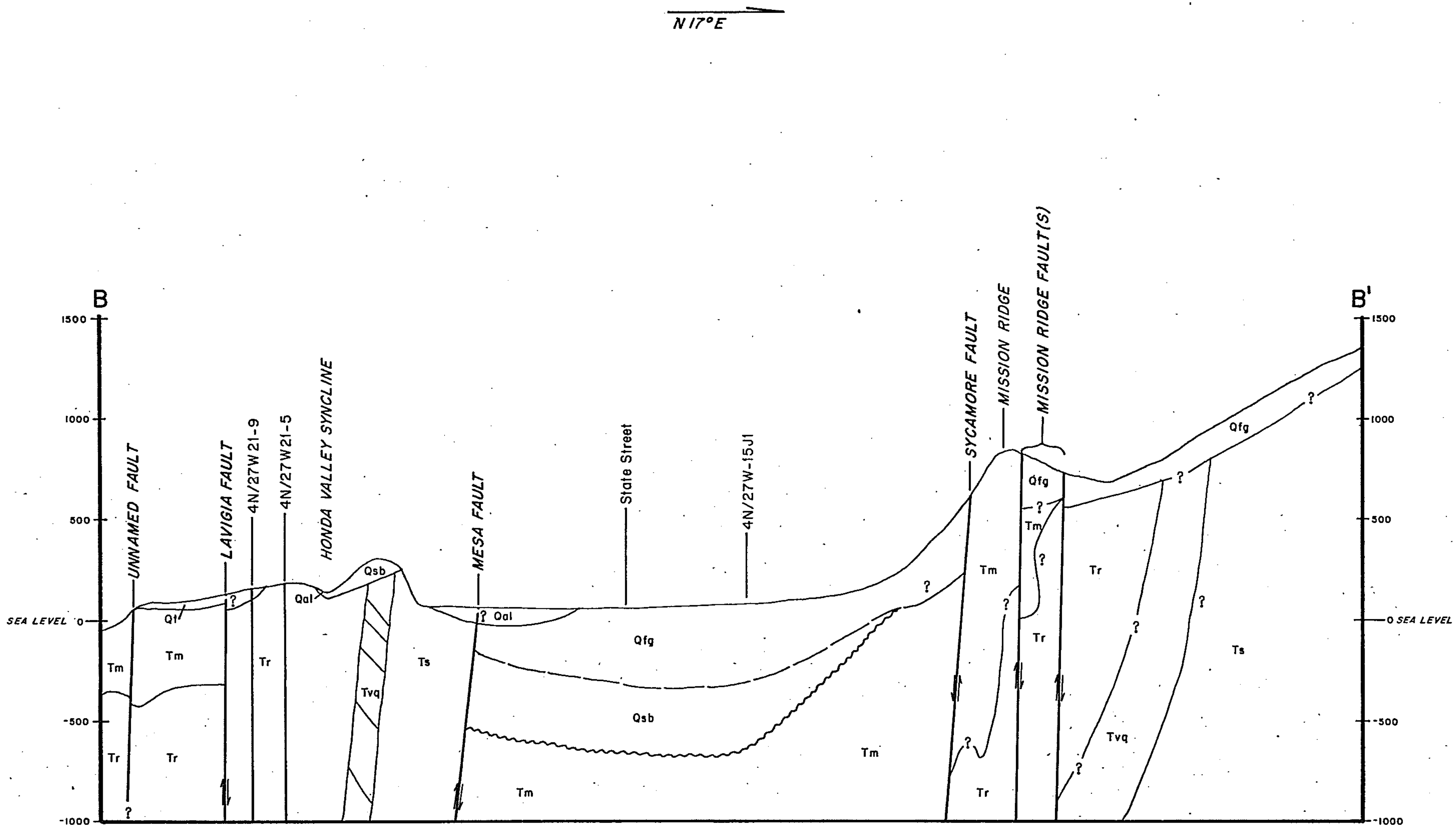
1" = 2000'

SCALE

MICHAEL F. HOOVER

Consulting Geologist

Plate 1a



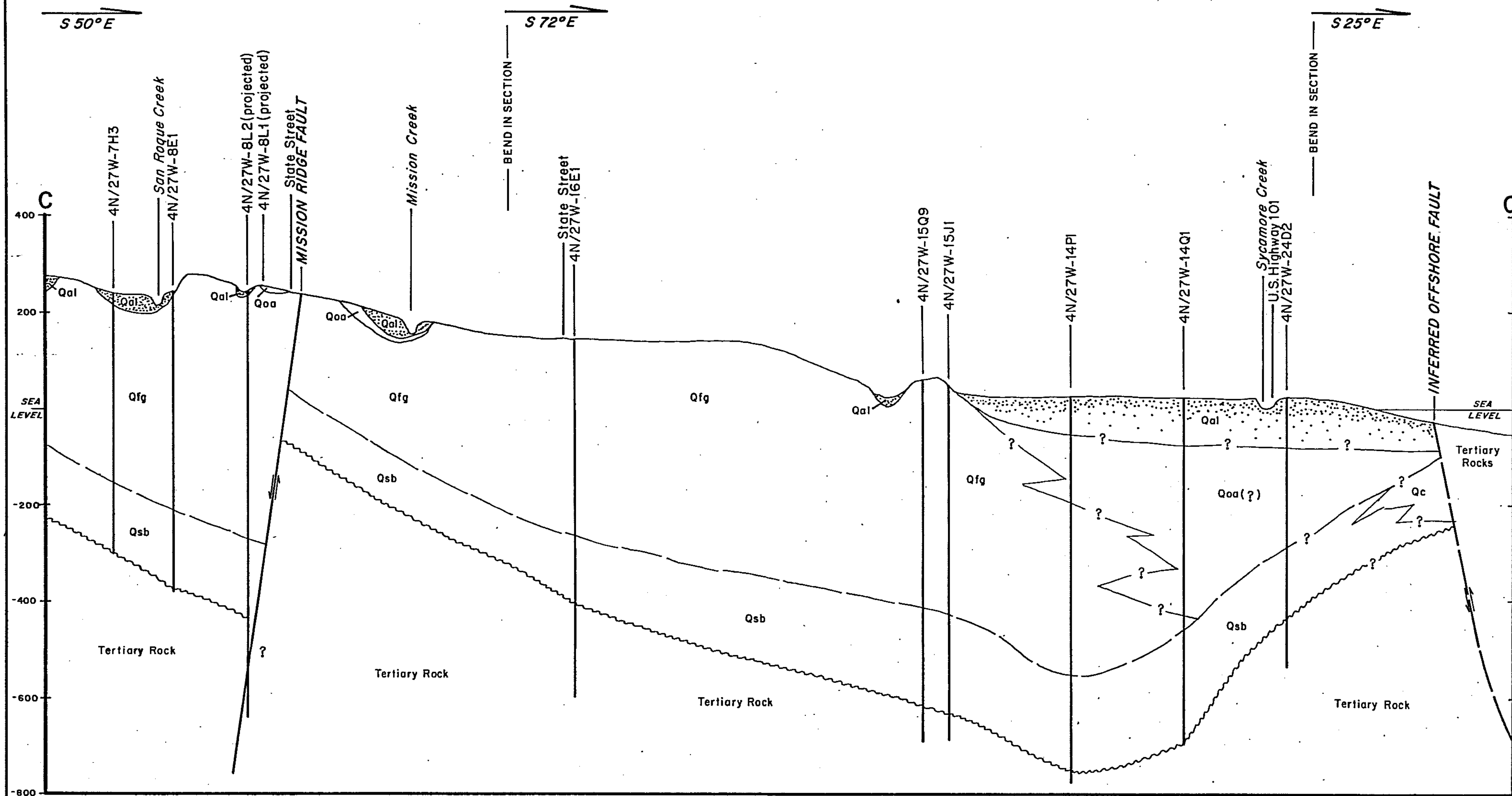
STRUCTURE CROSS SECTION ALONG LINE B-B'

For explanation of symbols, see Section A-A'

1" = 500'
vertical exaggeration x 4
1" = 2000'
SCALE

MICHAEL F. HOOVER
Consulting Geologist

Plate 1b



STRUCTURE CROSS SECTION ALONG LINE C-C'

For explanation of symbols, see Section A-A'

vertical exaggeration x10

1" = 200'

1" = 2000'

SCALE

MICHAEL F. HOOVER
Consulting Geologist

Plate 1c

File 142-001

Date 10-18-78 Rev. 1-1-79

By K. Frost

LEGEND

GEOLOGIC UNITS

Symbol	Description
Qaf	Artificial Fill
Qbs	Beach Sand
Qls	Landslide
Qal	Alluvium
Qt	Terrace Deposit
Qc	Casitas Formation
Tm	Monterey Shale

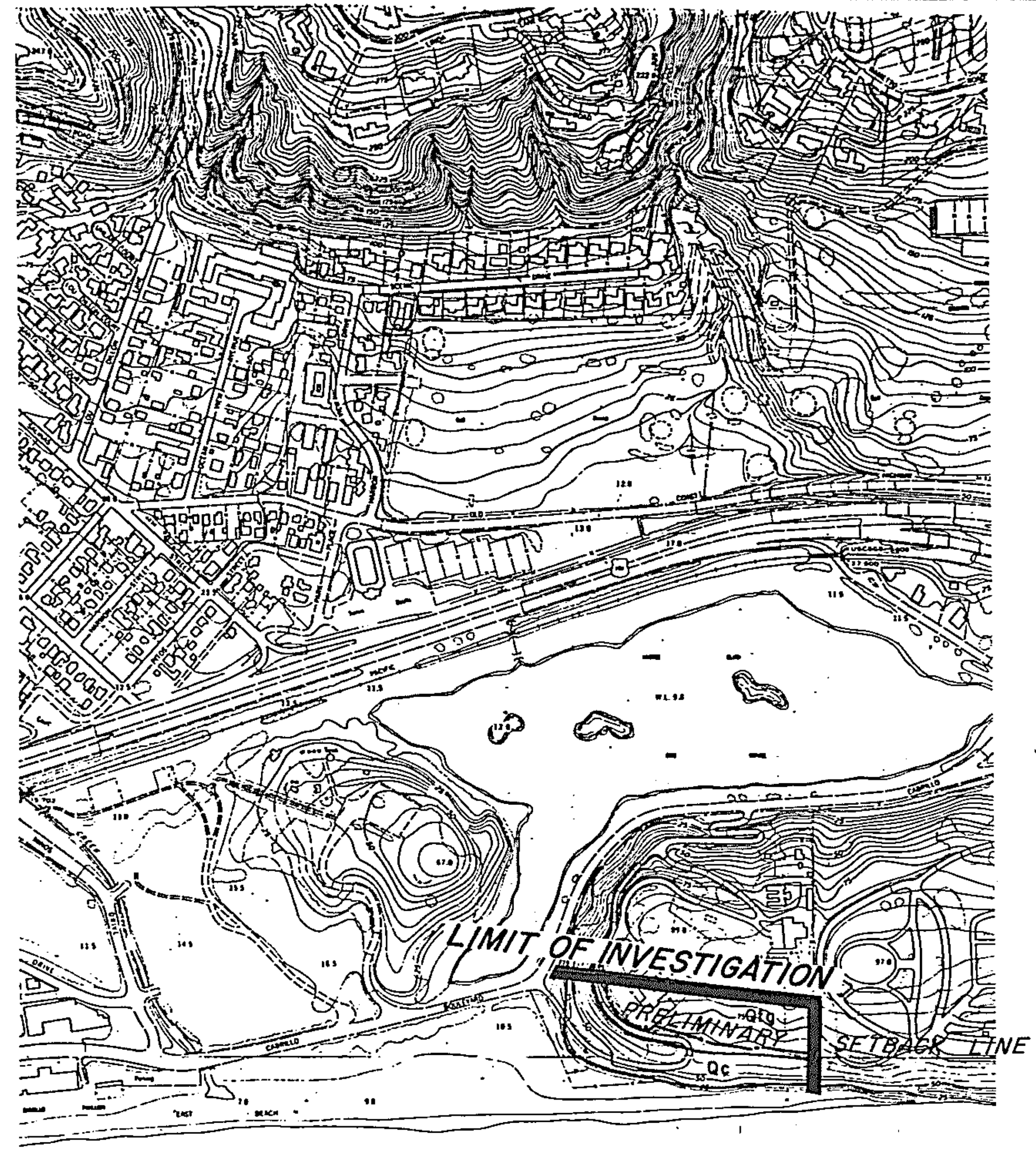
SYMBOL

- Limit of Investigation
- Prelim. Setback Line
- Contact between formations
- Fault
- Anticline
- Syncline
- Fractured Bedding
- Landslide. Arrows indicate direction of movement.
- Strike and dip of bedding (69)
- Strike of vertical bedding
- Overturned anticline
- Overturned syncline

Notes:

1. Geologic contact not always shown in order to preserve clarity. Bluff face is generally Monterey Shale (Tm), Mesa is generally 6 to 20 feet thick terrace deposit (Qt).

2. For complete description of geologic units and symbols on Coastal Hazards Maps see Plate 1.



N

0 600' 1200' 1800' 2400'

Scale: 1 inch=600 Feet

THE CITY OF
SANTA BARBARA
COASTAL HAZARDS MAP
GEOLOGIC STABILITY OF BLUFF

Prepared for:
Santa Barbara Environmental Quality Advisory Committee
Joan Kerns, Chairman
according to specifications provided by the
SB EQAC Geological Ad Hoc Committee
William A. Anikouchine, Chairman

MICHAEL F. HOOVER
Consulting Geologist

Plate 7

THE CITY OF
SANTA BARBARA
COASTAL HAZARDS MAP
GEOLOGIC STABILITY OF BLUFF

Prepared for:
Santa Barbara Environmental Quality Advisory Committee
Joan Kerns, Chairman
according to specifications provided by the
SB EQAC Geological Ad Hoc Committee
William A. Anikouchine, Chairman

0 600' 1200' 1800' 2400'

Scale: 1 Inch = 600 Feet

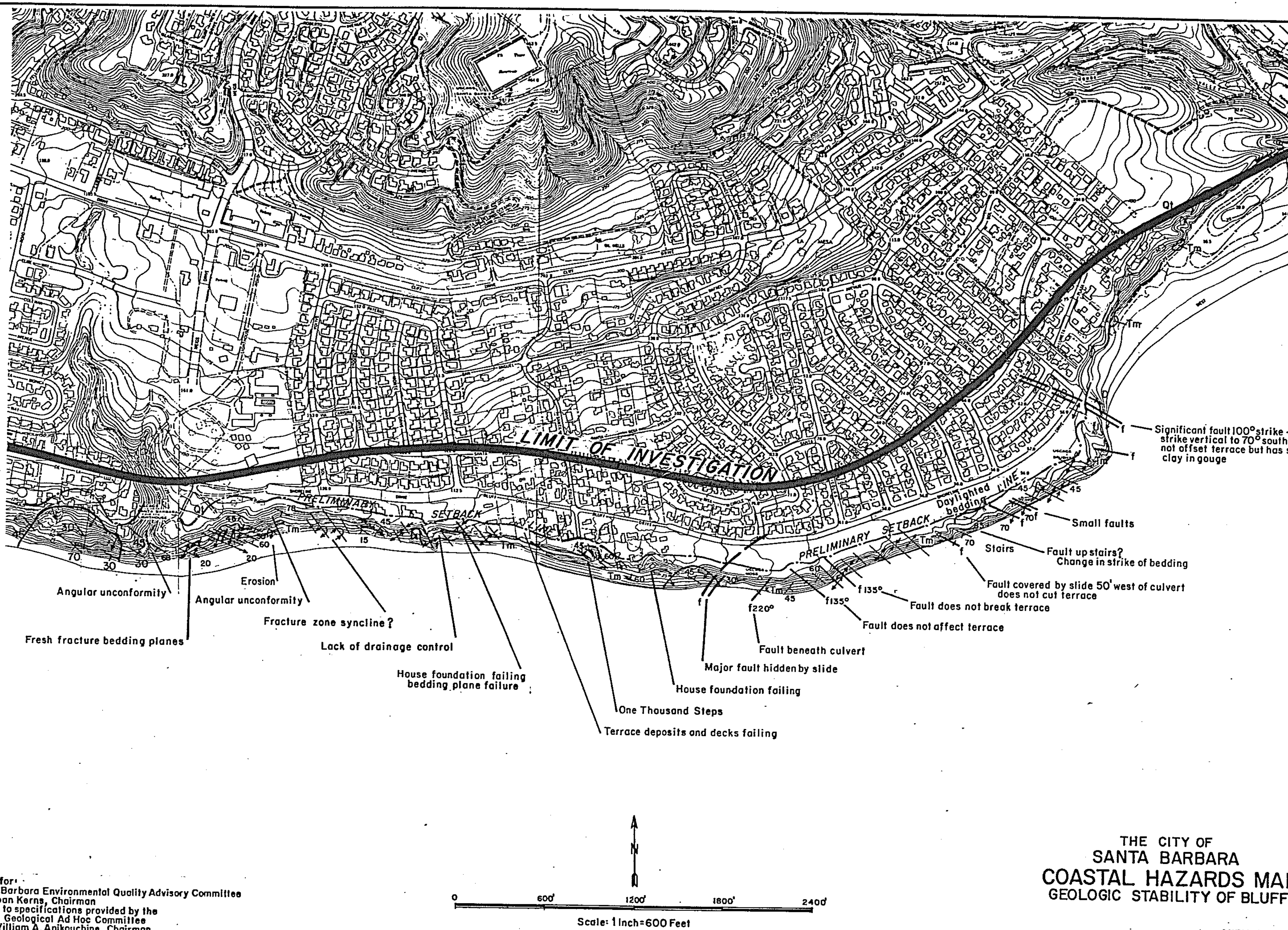
MICHAEL F. HOOVER
Consulting Geologist

Plate 7

File 142-001

By K. Frost Date 10·18·78 Rev. 1·11·79

File 142-001



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By K. Frost Date 10-18-78 Rev. 1-11-79