CEIP 79-18

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OPEN FILE REPORT 80-5 SF

GEOLOGY FOR PLANNING: GUADALUPE AND POINT SAL 7 1/2' QUADRANGLES, SANTA BARBARA AND SAN LUIS OBISPO COUNTIES, CALIFORNIA

California Division of Mines & Geology

(A report to the California Coastal Commission
funded in part under interagency agreement
number CEIPG 79-18. Coastal Commission funds
received from a Federal Coastal Energy Impact
Program Grant number 308 (c) -1)

by Richard T. Kilbourne (*) and Lalliana Mualchin (**)

CALIFORNIA DIVISION OF MINES AND GEOLOGY
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Sacramento, CA 95814

APPROVED:

T. E. Gay Jr.
for James F. Davis
State Geologist

This publication was prepared with financial assistance from the U.S. Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, under the provisions of the Federal Coastal Zone Management Act of 1972, as amended, and from the California Coastal Commission under the provisions of the Coastal Act of 1976.

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GEOLOGY FOR PLANNING: POINT SAL AND GUADALUPE 7 1/2' QUADRANGLES, SANTA BARBARA AND SAN LUIS OBISPO COUNTIES, CALIFORNIA

ABSTRACT

Fourteen categories of geologic data of varying importance for planning and zoning are documented in this report for the area of the Point Sal and Guadalupe 7 1/2' Quadrangles. They include:

1. active sand dunes,
2. Quaternary landslides,
3. regions of potential seismically induced liquefaction,
4. unstable slopes,
5. faults,
6. maximum credible ground shaking,
7. areas of fossil fuel production,
8. diatomite deposits,
9. 100-year flood plain with levee integrity,
10. 100-year flood plain with levee failure,
11. Twitchell Dam failure flood plain,
12. height of 100- and 500-year distant source tsunami runup,
13. groundwater aquifer recharge areas, and
14. unique geologic features of significant scientific or educational value.

All categories of data, except maximum credible ground shaking are depicted on 1:24,000 scale quadrangle maps (plates la-b, 2a-b).

The report represents a compilation of available published and unpublished data and is not the result of extensive field investigation. It is not intended to take the place of geotechnical investigations that would normally precede any specific land-use. It is intended to be useful to planners, developers, and reviewers involved in land use planning. The relative weight of these constraints in the planning, zoning, or site selection process needs to be evaluated by persons familiar with cost-benefit assessments and risk analysis. These processes are not implied in this report. The existence, description, location, and published documentation, and the need for further studies of geologic constraints are presented as a data base for land use planning.

INTRODUCTION

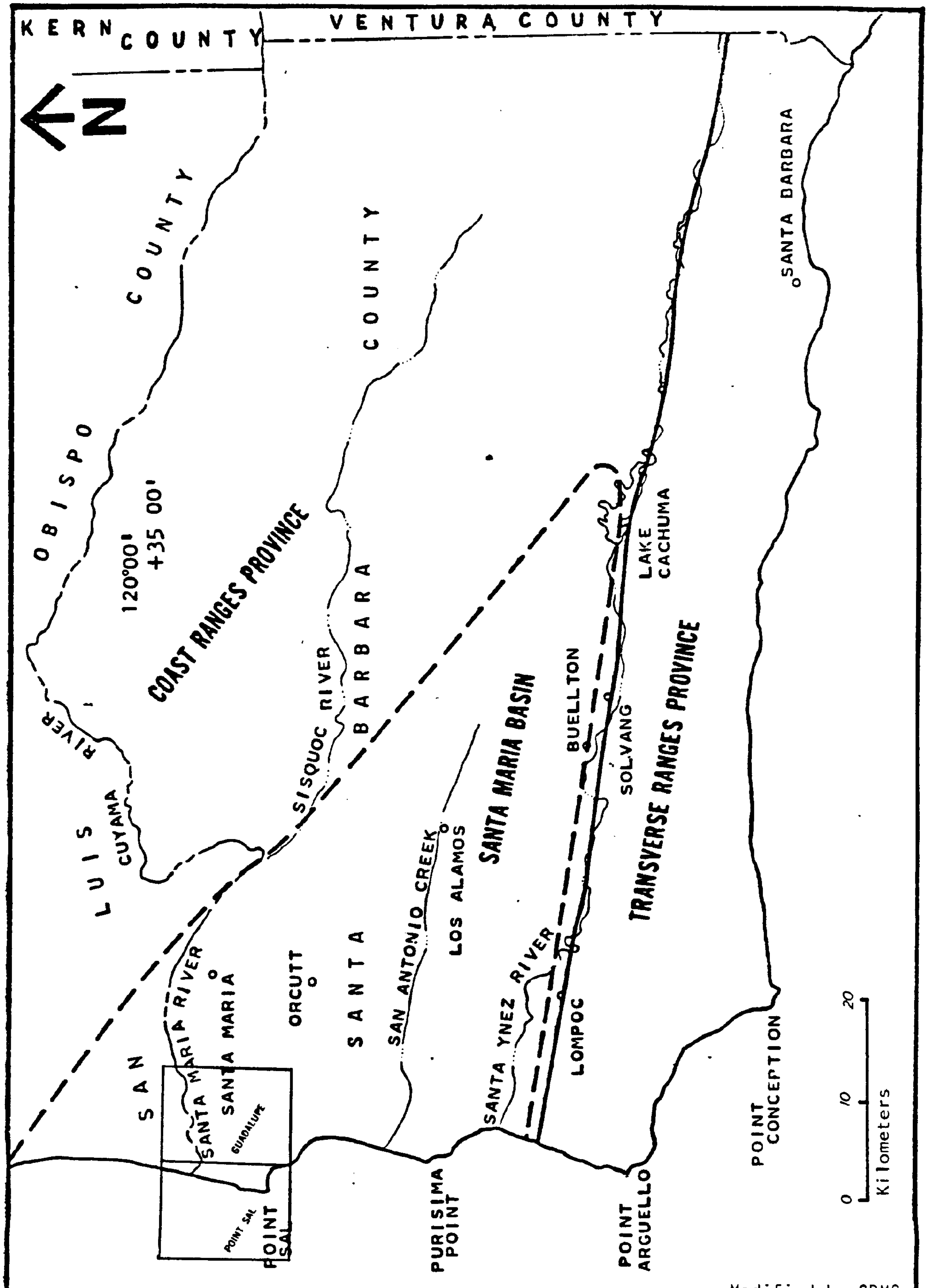
The purpose of this investigation is to identify geologic conditions significant to planning in the Point Sal and adjoining Guadalupe 7 1/2 minute Quadrangles. Section 30253 (1) of the California Public Resources Code specifically requires the Coastal Commission to see that new development "minimizes risk to life and property in areas of high geologic, flood and fire hazard." This report locates selected geologic hazards present in this portion of the coastal zone and will aid in considering this region for the siting of energy or other facilities in the future. This report is primarily an accumulation of presently available published and unpublished data and involves no significant amount of field investigation. It in no way is intended to take the place of detailed geotechnical investigations normally preceeding site certification and construction for energy facilities. It is intended to identify conditions pertinent to energy facility siting, provide references and sources of further information, and to identify information gaps. The study was conducted by the California Division of Mines and Geology and was funded jointly by the California Coastal Commission (80%) and the California Division of Mines and Geology (20%). Coastal Commission funds were ultimately derived from a Federal Coastal Energy Impact Program Grant number 308 (C) (1).

The area of study was specified by the Coastal Commission as one of many within and adjacent to the California Coastal Zone where geologic hazard studies would be warranted.

GEOLOGIC SETTING

The Guadalupe and Point Sal 7 1/2 minute quadrangles cover an area near the northwestern edge of the Santa Maria basin (Figure 1). The geologic setting of the area of this investigation is that of a Neogene (Late Tertiary/Quaternary) basin in a transitional seismo-tectonic region between the southern Coast and the western Transverse Ranges (figure 1). The basin has been named the Santa Maria basin after the principal town in the area. In the sense described by Woodring and Bramlette (1950), and Dibblee (1978), the Santa Maria basin is an asymmetric, deeply subsided Neogene trough, with an axis trending northwest through the Los Olivos area of Santa Ynez Valley, Los Alamos Valley, and the southwestern margin of the Santa Maria Valley. Offshore investigations indicate that this trough extends from Santa Maria Valley northwest offshore and southwest of the Santa Lucia Mountains for more than 320 kilometers (Hoskins and Griffiths, 1971).

Under the axial part of this trough, lies a sheared Franciscan and Knoxville basement complex similar to the lithology of the Santa Lucia Range. Oil well drilling logs indicate that up to 3,500 meters of Neogene sediments overlie this basement. Cross sections of the Casmalia Hills and Santa Maria Valley by Woodring and Bramlette (1950) and of the Lompoc, Orcutt, and Santa Maria Valley oil fields by Krammes and Curran (1959) suggest that the Santa Maria basin contains a major high angle reverse slip fault. This fault was portrayed by Crawford (1971) as the Orcutt frontal fault.



MAJOR STRUCTURAL PROVINCES

Figure 1 SHOWING POINT SAL AND GUADALUPE 7.5 MINUTE QUADRANGLES

Modified by CDMG
From
Dames & Moore
1978

PREVIOUS WORK

Due to the occurrence of valuable mineral resources and the proposed siting of critical facilities (e.g. the proposed Point Conception LNG site and the Diablo Canyon Nuclear site), the geology of the region, including the Santa Maria basin, has been intensively investigated. A bibliography of the region would include hundreds of references. Discussion of all the references is not feasible within the scope of this report. A few references judged to contain useful documentation of geologic conditions pertinent to planning are annotated in this section.

Woodring and Bramlette (1950) published a comprehensive report on the geology and paleontology of this region as part of a U.S.G.S. study of oil producing districts in California. Their report contains an extensive annotated bibliography that summarizes the earlier geologic publications back to before the turn of the century. Their 1:24,000 scale geologic map on a photo base of the Santa Maria basin conservatively contains four categories of reliability in their symbols for both faults and formation boundaries. Later, Crawford (1971) interpreted the subsurface structural geology of the Santa Maria basin as it pertains to oil production and reserves of the area. In a study concentrating on the sea water intrusion problems of the Pismo-Guadalupe area, Cummings, et al. (1970) have compiled and correlated much shallow water well data. The resulting maps, cross-sections, and report detail the hydrogeologic relationships of the Pliocene, Pleistocene, and recent strata of the region.

The siting of the Diablo Canyon nuclear facility and the proposed siting of the Point Conception LNG terminal, have resulted in the publication of several detailed seismo-tectonic studies of the region. Several important articles and an extensive bibliography are found in CDMG Special Report 137 of the Hosgri fault symposium volume edited by Silver and Normark (1978). In studies conducted for the Nuclear Regulatory Commission, Buchanan- Banks, et al. (1978), compiled a recency of faulting map for coastal south central California including the Santa Maria area. In an analysis of geologic/ seismic hazards to the Point Conception LNG terminal site, Dibblee (1978) prepared a report covering the Santa Maria basin for Santa Barbara County. The California Division of Mines and Geology is currently evaluating these and other studies on this same subject. The Final Safety Analysis Report and Appendices for Pacific Gas and Electric Company's Diablo Canyon Units 1 and 2 Nuclear Power Plant (Earth Sciences Associates, 1974) contains useful geologic/seismic data for a region that includes the Santa Maria basin.

I. GEOLOGIC HAZARDS

1. Fault Surface Rupture

The hazard of fault surface rupture is clearly associated with traces of active and potentially active faults. For the purpose of this preliminary evaluation, a fault is considered active if it can be shown to cut Holocene strata and potentially active if it has not been shown to be overlain by strata at least 1.8 million years old (Pleistocene). Recognition and avoidance of such fault traces are generally the only reliable mitigation of surface rupture hazard.

In the evaluation of this hazard for the Point Sal and Guadalupe 7 1/2' Quadrangles, geologic literature was surveyed for map locations of fault traces within the bounds of the quadrangles. Owing to the long known fossil fuel resource of the region, the geologic literature is abundant and often emphasizes structural geology. Though more than forty references were examined to evaluate the published details of area faults and the surface rupture hazard, the publications by Woodring and Bramlette, 1950; Earth Sciences Associates, 1974; Buchanan-Banks, et al., 1978; and Payne , et al., 1978, were the principal references used in the compilation. When all this literature is compiled on one map, there is possibly an overstatement of the number of faults. This can happen when a subsurface fault recognized from drill core data is projected to the surface on one map and shown as a subsurface fault on another. It can also occur as the result of a drafting error. If a fault's existence is in doubt from our limited field work and subjective evaluation, it is queried on plates 1a and 2a. These queries were not in the original references used in the compilation. Plates 1a and 2a (in pocket) show the potentially active faults (defined above) compiled for the Point Sal and Guadalupe Quadrangles. No faults defined as active were documented.

In spite of the possible overstatement of the number of faults, it is still highly unlikely that all of the potentially active faults that exist in the area are shown on plates 1a-2a. To do this would require detailed field studies usually involving trenching, age dating and geophysical surveys that are beyond the scope of the present study. Table 1 shows references used for compilation of the faults appearing on Plates 1a and 2a.

2. Potential Earthquake Faults

Seismic shaking can severely damage structures unless adequate precautions are taken in site selection and structural design. The information on which such decisions must be based includes identification and delineation of those faults capable of generating earthquakes. This portion of this report is directed toward the identification of faults that are perceived to be potential sources of damaging earthquakes in the Guadalupe and Point Sal 7 1/2' Quadrangles. Table 2 is a list of these faults.

The preparation of this list was guided by the philosophy that inclusion of questionable evidence of fault hazard should lead to proper investigation, whereas omission of such evidence would lead to the inference that no hazard exists. The list was prepared only from examination of geologic literature and not from original field work. When two or more maps exist in the literature with differences in a fault's length or existence, the more conservative (longer) length and the existence (rather than non-existence) were chosen for consideration.

TABLE 1: SOURCES OF FAULTS DEPICTED ON PLATES 1a and 2a of POINT SAL AND GUADALUPE 7½' QUADRANGLES

NAME	FAULT NUMBER	SOURCE
Pezzoni	5a	Woodring and Bramlette, 1950
	5b	Woodring and Bramlette, 1950
Pezzoni	5c	Williams and Holmes, (1945) Woodring and Bramlette, (1950)
	5d	Woodring and Bramlette (1950)
Orcutt Frontal	5e	Krammes and Curran (1959) Crawford (1971) Earth Sciences Associates (1974) Payne _et_ _al_., (1978)
	5f	Earth Sciences Associates (1974) Payne _et_ _al_., (1978)
	5g	Earth Sciences Associates (1974) Payne _et_ _al_., (1978)
	5h	Earth Sciences Associates (1974) Payne _et_ _al_., (1978)
	5i	Earth Sciences Associates (1974) Payne et al., (1978)
	5j	Earth Sciences Associates (1974) Payne _et_ _al_., (1978)
	5k	Earth Sciences Associates (1974) Payne _et_ _al_., (1978)
	5l	Woodring and Bramlette (1950)
	5m	Earth Sciences Associates (1974) Payne _et_ _al_., (1978)
	5n-s	Woodring and Bramlette (1950)

TABLE 2 FAULTS OF PROBABLE SEISMIC SIGNIFICANCE TO POINT SAL AND GUADALUPE 7 1/2' QUADRANGLES

FAULT NAME	PUBLISHED LENGTH IN KILOMETERS	DISTANCE AND DIRECTION TO SITE (*) IN KILOMETERS	AGE OF STRATA CUT Buchanan-Banks et.al., 1978	PROBABLE SENSE OF MOVEMENT	SOURCES
PEZZONI-CASMALIA-LOS ALAMOS-BASELINE (= ORCUTT FRONTAL of Crawford, 1971)	90+	2.2 NE	Holocene	high angle reverse, S.W. side up	Woodring and Bramlette (1950), Krammes and Curran (1959), Crawford (1971), Dibblee(1978), Hall (1978)
SANTA MARIA RIVER-FOXEN CANYON-LITTLE PINE	114	12 SW	Late Pleistocene	high angle right-lateral oblique slip, northeast side up	Woodring and Bramlette (1950), Worts (1951), Jennings (1959), Dibblee (1966), Jennings(1975), Buchanan-Banks, et.al., (1978)
BRADLEY CANYON (= SANTA MARIA of Jennings, 1975)	12	13 W	Pleistocene	45° angle reverse, northeast side up	Canfield (1939), Jennings (1975), Hall (1978)
SAN GREGORIO-HOSGRI	400±	17.5 E	Holocene	right lateral slip, oblique N.E. side up	McCulloch et.al. (1977), Buchanan-Banks, et.al. (1978), Silver (1978)
GAREY (= BRADLEY CANYON of Jennings, 1975)	25	19 W	Late Cenozoic	undetermined	Jennings (1975), Hall (1978)
OCEANIC-W. HUASNA	120+	21 W	Late Pleistocene	high angle, possibly left-lateral strike slip	Hall (1973), Earth Sciences Associates (1974), Buchanan-Banks, et.al. (1978)
SAN MIGUELITO	20	22 S	Pliocene	predominantly dip slip southwest side up	Hall and Surdam (1967), Earth Sciences Associates (1974), Hall (1978)
EDNA	43	23 S	Pleistocene	high angle dip slip northeast side up	Earth Sciences Associates (1974), Buchanan-Banks, et.al. (1978), Hall (1978)

(*) Distance to site is measured as closest point on fault to center of Guadalupe 7 1/2' quadrangle (an arbitrary point, not a site location).

TABLE 2 CONTINUED

SUEY	24	24	W	Late Cenozoic	high angle dip slip northeast side up	Jennings (1959)
EAST HUASNA	33	30	SW	Late Cenozoic	right lateral oblique slip northeast side up	Hall and Corbato (1967) Earth Sciences Associates(1974) Buchanan-Banks, _et.al._ (1978)
SUR-NACIMIENTO	290	35	SW	Late Cenozoic	high angle reverse, northeast side up	Page (1970) Earth Sciences Associates(1974)
RINCONADA	300+	39	SW	Late Pleistocene	predominantly right lateral strike slip	Dibblee (1972) Earth Sciences Associates(1974)
SOUTH CUYAMA-OZENA	100	42	SW	Pliocene	reverse, southwest side up	Dibblee (1978)
LA PANZA	73	47	SW	Pliocene	reverse, southwest side up	Dibblee (1973)
SANTA YNEZ-PACIFICA	150+	47.5	N	Late Pleistocene	variable dip, left lateral oblique slip south side up	Dibblee (1950) Earth Sciences Associates(1978)
SANTA LUCIA BANK	135±	67	E	Holocene	dip slip	Hoskins and Griffiths (1971) Earth Sciences Associates(1974)
SAN ANDREAS	1200+	73	SW	Holocene	right lateral strike slip	Jennings (1975)

An important data gap exists in this compilation in that no literature was examined showing geologic structure of the offshore area in a 10 kilometer wide belt between Point Sal and Pismo Beach. This area is particularly important, in that it is perpendicular to the regional structure and, if faults exist in this region, they would probably connect with existing land based faults or to branches of the presumably active Hosgri fault. This offshore area is currently under investigation by the U.S.G.S. Their analysis is in progress and has not yet been published (July 1, 1980).

Information to fill this gap might be obtained upon publication of the U.S.G.S. data, through the purchase of proprietary oil company data, or by conducting independent seismic refraction and reflection surveys.

3. Historic Seismicity

Pre-1900

The Guadalupe area probably has experienced ground shaking of different intensities, even before recorded historical time, from earthquakes in central and southern California. The following descriptions of pre-1900 earthquakes in the coastal region from Monterey to Santa Barbara Channel are taken from an on-going investigation of the CDMG earthquake catalog project (Toppozada, *et al.*, 1979) and Earthquake History of the United States (Coffman and von Hake, 1973). These are presented chronologically to show that the Guadalupe area needs careful

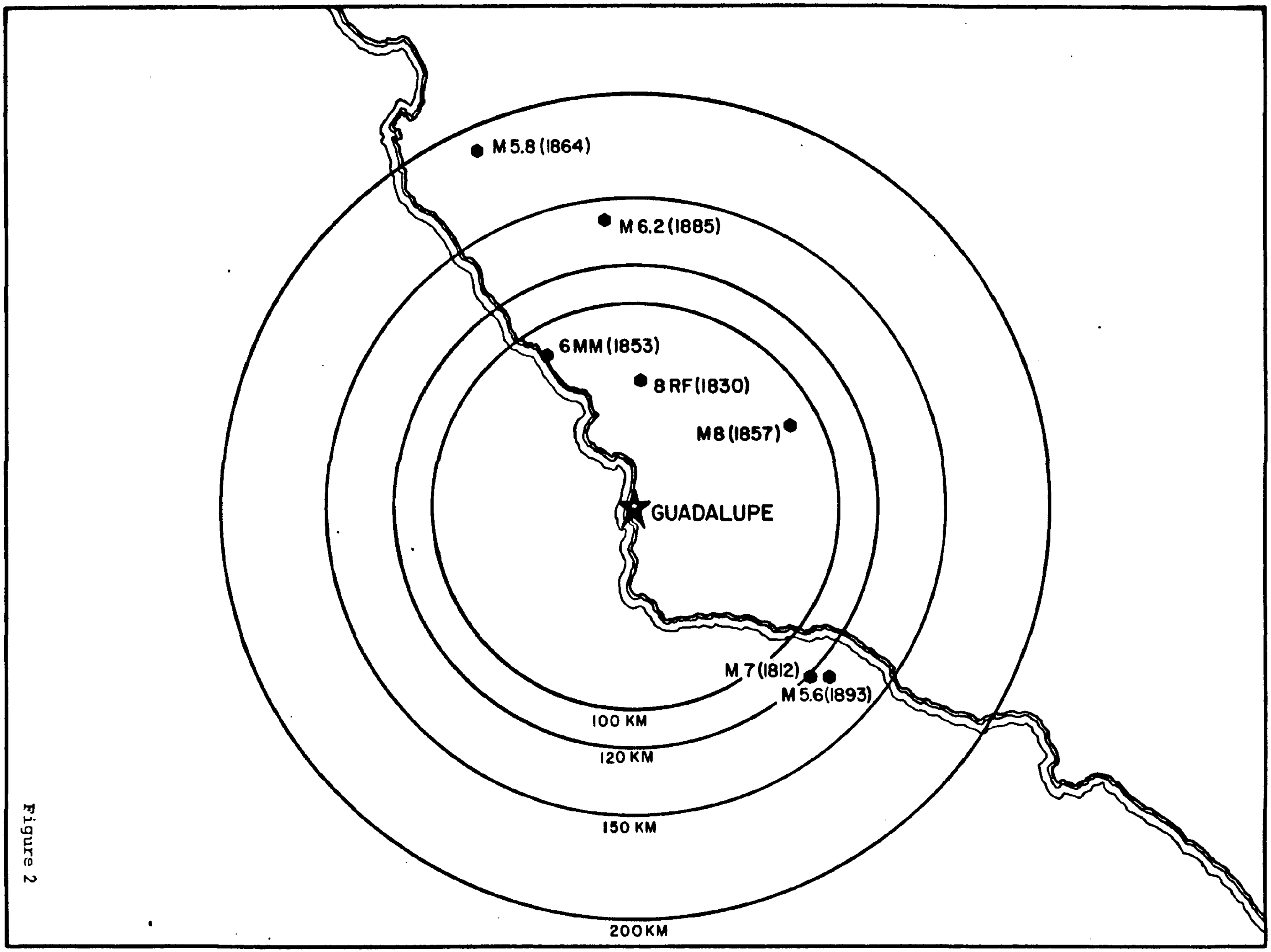


Figure 2

PRE-1900 LARGER EARTHQUAKES FOR GUADALUPE SITE

(Post-1900 earthquakes are shown on plate 3.)

evaluation of seismic hazard from coastal earthquakes for siting critical facilities. Figure 2 shows seven larger pre-1900 earthquakes ($M \geq 5.5$; $I \geq$ VI MM) from Monterey to the Santa Barbara Channel and plate 3 shows epicenters of earthquakes of magnitude greater than 3 within 120 km of the center of the Guadalupe Quadrangle from 1900 to 1975. The larger area for the epicenter map of pre-1900 earthquakes $M \geq 5$ is shown on figure 2 because the locations are more uncertain, whereas a smaller region was selected for post-1900 earthquakes.

<u>1812 December 21</u>: Epicenter 34.2N; 119.7W; Magnitude 7.2. (Santa Barbara Channel, damage from Lompoc to San Fernando; Tsunami?)

This shock was damaging in Santa Barbara, Ventura, and northern Los Angeles Counties. A strong and damaging foreshock alarmed inhabitants and sent them fleeing from buildings. This, undoubtedly, saved many lives when the main shock occurred. Some people were injured, but there were no deaths reported. The church of Purisima Mission and many of the mission buildings were destroyed. At Santa Ynez Mission, a corner of the church fell, all roofs were ruined, walls cracked, and many new homes were demolished. At Santa Barbara, all mission buildings were severely damaged and the church was later rebuilt. At the presidio, some buildings were ruined and the remaining structures were damaged. At San Buenaventura Mission, the tower was wrecked and much of the facade of the church had to be rebuilt. At San Fernando Mission, 30 beams had to be used to keep the walls from falling. Strong aftershocks occurred until February and shocks of less intensity continued until April 1813.

This earthquake may or may not have generated a tsunami. A recent examination of evidence for a tsunami by Marine Advisers, Inc. (1965) neither proves nor disproves the occurrence of tsunami waves associated with this earthquake. Mission records at that time mention fear of the sea, but give no details. Reports of a tsunami, which do not appear in the literature until many years after the earthquake, are based on the memory of several individuals and are poorly documented.

1830 Date unknown: Epicenter 35.5N; 120.6W. Intensity VIII RF, which is approximately VII-VIII MM. Damage at San Luis Obispo and Santa Margarita. Church was damaged in San Luis Obispo.

1852 December 17: It is doubtful that this event occurred; this conclusion is supported by unpublished CDMG research relative to historic California seismicity and is therefore not shown on figure 2.

1853 February 1: Epicenter 35.6N; 121.1W; Intensity VI RF, which is about V-VI MM. San Luis Obispo County. San Simeon. Violent shocks damaged houses.

1857 January 9: Epicenter 35.3N; 119.8W, Magnitude 8 (San Andreas fault rupture from Parkfield to Cajon; Near Fort Tejon).

Violent shock. A ground crack 65 km long was observed in the vicinity of Fort Tejon, an army post about 6.5 km from the San Andreas fault between Los Angeles and San Francisco. Near Tejon, a corral was converted by horizontal dislocation of the ground into an open S-shaped figure; at the Fort, buildings and large trees were thrown down. The roof of the mission church at Ventura collapsed. Artesian wells in the Santa Clara Valley (near Ventura) ceased to flow, and in other places, increased their flow. Several new springs were formed near Santa Barbara. There were large fissures in a number of places. Wood (1955) and Allen (1925) have considered this shock potentially the most destructive in the Coast Ranges since the arrival of Europeans in the region.

<u>1864 February 26</u>: Epicenter 36.5N; 121.5W; Magnitude 5.9, possibly Monterey County. Preliminary estimates of intensity by CDMG are: V MM at San Jose, Stockton, San Francisco; VI MM at Monterey and Watsonville.

<u>1885 April 12</u>: Epicenter 36.2N; 120.8W, Magnitude 6.2 (Monterey, San Benito, and Fresno Counties). San Andreas fault (?).

This shock was felt strongly at Martinez, Santa Rosa,and Healdsburg, and may have originated on the San Andreas fault, in the thinly settled region east of King City, Monterey County, although the actual location is uncertain. Chimneys were thrown down at Las Tablas, 30 miles (48 km) northwest of San Luis Obispo. Slight damage occurred at Salinas, San Luis Obispo, and Monterey; felt to Marysville on the north, Keller on the east, and Ventura on the south. Little damage.

1893 May 19: Epicenter, 34.2N; 119.6W. Magnitude 5.8 (Santa Barbara Channel, southeast of Ventura).

Felt from San Diego to Lompoc and inland as far as San Bernardino. Highest intensity occurred in the region southeast of Ventura. Duration at Ventura was about 15 seconds. No damage was reported, but it may have been potentially destructive. Probable submarine origin.

Post-1900

There were 39 earthquakes of magnitude greater than M5.5 and/or intensity greater than VI MM within 120 km of the center of the Guadalupe 7 1/2' Quadrangle for 1900-1975 (Toppozada, *et al.*, 1978; Real, *et al.*, 1978). Post-1900 earthquakes within 120 km of the center of the Guadalupe quadrangle include the 1922 Cholame Valley earthquake (M 6.5), the 1925 Santa Barbara Channel earthquake (M 6.2), the 1934 Parkfield earthquake (M 6.0), and the M6.0 earthquake near Bryson in 1952. For the purpose of this study, it is considered that the 1927 Lompoc earthquake is the most significant earthquake for the study area.

Hanks (1979) presented the epicenter of this earthquake as determined by several authors and by himself as presented in figure 2A. It can be seen from this figure that the epicenter suggested by Gawthrop (1978) is closest to the study area under consideration. None of the suggested epicenters are absolutely correct due to unreliable factors (distribution of seismographic stations, observation of arrival times, etc.) and hence, it would be prudent to assume that a repeated earthquake could be located near or about the same place as was suggested by Gawthrop (1978).

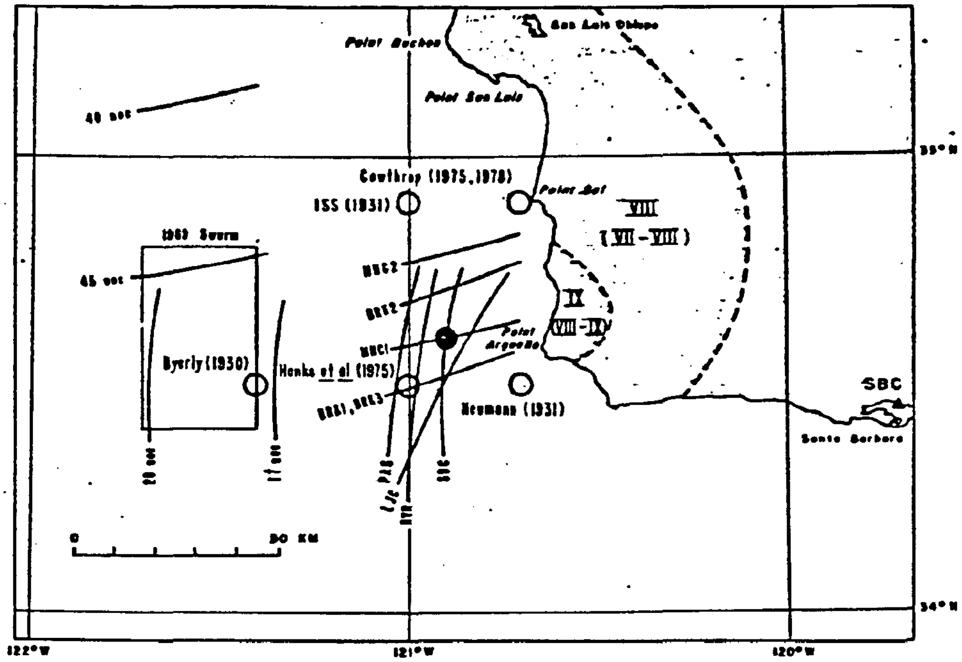


Figure 2A. EPICENTERS OF 1927 LOMPOC EARTHQUAKE

Sources (Chronological)

BYERLY, P. (1930). The California earthquake of November, 1927, Bulletin of the Seismological Society of America, V.20, 53-66.

NEUMANN, F. (1931). Seismological report-October, November, December, 1927, U.S. Coast Geodetic Survey. Series 503.

ISS (1931). International Seismological Summary for 1927, October, November, December, University Observatory, Oxford.

HANKS, T.C., J.A. HILEMAN, and W. THATCHER (1975). Seismic moments of the larger earthquakes of the Southern California Region, Bulletin of the Geological Society of America, v.86, 1131-1139.

GAWTHROP, W. (1975). Seismicity of the Central California coastal region, U.S. Geological Survey Open File Report 75-134.

GAWTHROP, W. (1978). The 1927 Lompoc, California, earthquake, Bulletin of the Seismological Society of America, v.68, 1705-1716.

HANKS, T.C. (1979). The Lompoc, California, earthquake (November 4, 1927; M=7.3) and its aftershocks, Bulletin of the Seismological Society of America, v.69, 451-462.

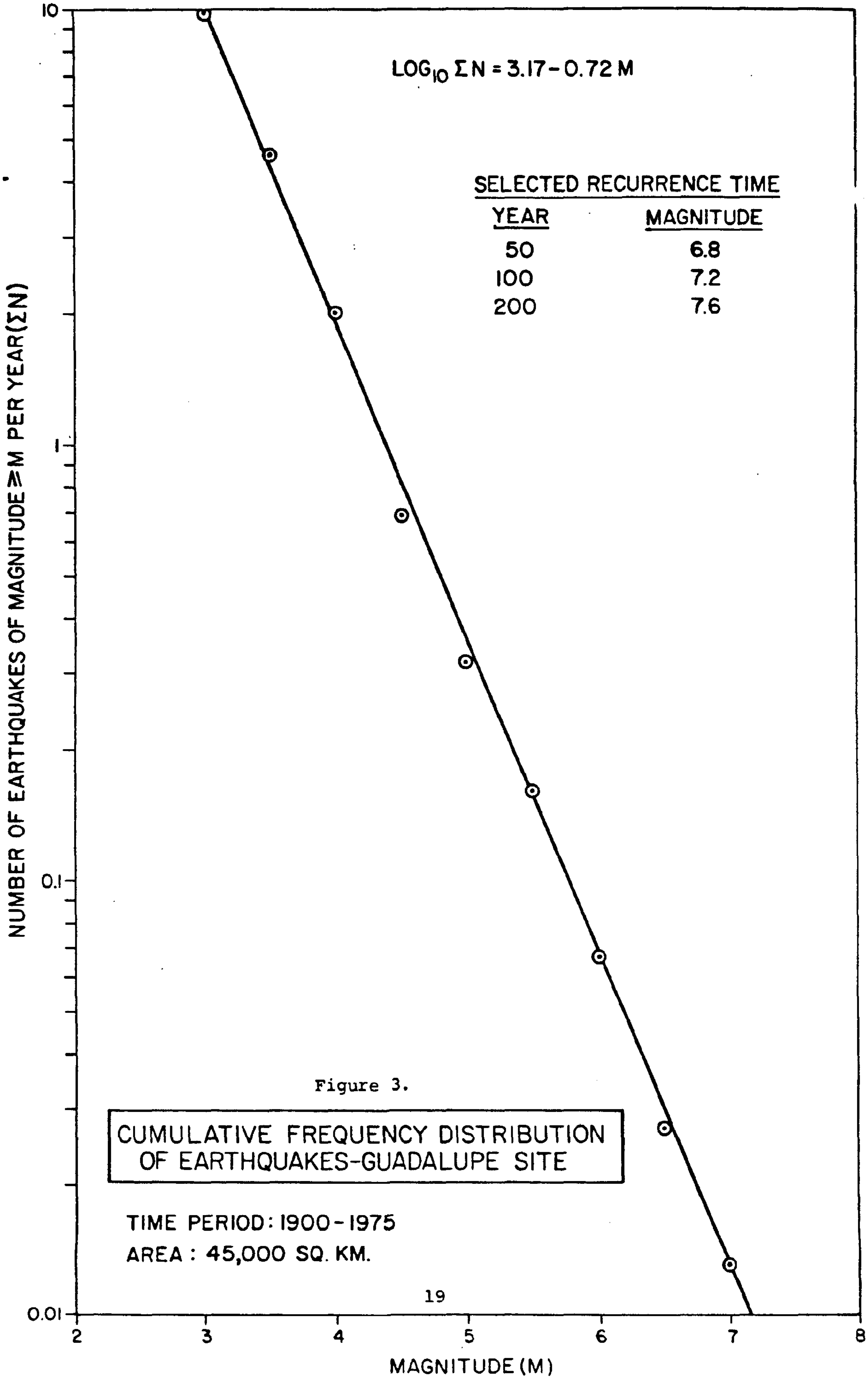
Ground shaking from such an earthquake would cause significant damage in the Guadalupe and Point Sal 7 1/2' Quadrangles. More study is needed to evaluate ground shaking for such an event.

4. Recurrence of Earthquakes

Seismicity data from the CDMG Earthquake Catalog for the period 1900- 1975 (Real, Toppozada, and Parke, 1978) for the area within 120 km of the center of the Guadalupe Quadrangle has been used to estimate the return period of earthquakes using the relation $\log \sum N = a - bM$.

In this equation, $\sum N$ is the number of earthquakes per year of magnitude M and greater for the area (about 45,000 square km) considered, and "a" and "b" are constants to be determined from a plot of $\log \sum N$ versus M on semi-logarithmic paper. Pre-1900 earthquakes are probably incomplete, especially for magnitudes less than 5.0 and hence are not considered in the recurrence analysis.

In the analysis, the seismicity data was normalized with respect to the time period (about 75 years; 1900-1975), but not with the area. The minimum magnitude for the analysis is M3 and it is most likely that magnitudes less than M4 are incomplete for the period considered. In future analysis, consideration should be given to completeness of data. The present study is preliminary and subject to revision when completeness of data is considered.



SELECTED RECURRENCE TIME

YEAR	MAGNITUDE
50	6.8
100	7.2
200	7.6

Figure 3.

CUMULATIVE FREQUENCY DISTRIBUTION OF EARTHQUAKES-GUADALUPE SITE

Figure 3 shows the recurrence curve. The constants "a" and "b" are determined to be 3.17 and 0.72, respectively. The 50-, 100-, and 200- year earthquakes are about M6.7, M7.2, and M7.6, respectively. The values of these magnitudes might increase slightly when completeness of data is considered.

5. Maximum Credible Earthquakes (MCE)

A number of methods are proposed in the literature and technical reports for estimating the magnitude of an earthquake that could be associated with a particular fault. Usually, it is assumed that half the fault length ruptures in the event of the MCE (Slemmons, 1977, pp. 111, 116). The magnitudes of MCE in this study are based on equations relating magnitudeand fault rupture length for different fault types suggested by Slemmons (1977) and Mark (1977), and for North America faults by Slemmons (1977) and magnitude and fault rupture area by Wyss (1979).

Magnitude and fault rupture length relationship may depend on geographic regions (Acharya 1979). The most recent study relating magnitude and fault rupture area (Singh et al., 1980) does not change substantially the relationship suggested by Wyss (1979) for interplate earthquakes such as those occurring on faults in this report.

Table 3 Maximum (Credible) Earthquakes

Fault	1/2 Fault Length (Km)	Distance (Km)(*)	MCE (M)	Bedrock Acceleration (g)(**)
Pezzoni-Casmalia Los Alamos-Baseline	45	2.2	6.8-7.5	0.68-0.73
Santa Maria River Foxen Canyon-Little Pine	57	12	6.9-7.3	0.42-0.45
Bradley Canyon	6	13	5.5-6.9	0.21-0.40
San Gregorio-Hosgri	200±	17.5	7.5-7.8	0.40-0.42
Garey	13	19	6.0-6.3	0.21-0.24
Oceanic-W. Huasna	60	21	6.9-7.2	0.30-0.33
San Miguelito	10	22	5.8-6.2	0.16-0.20
Edna	22	23	6.4-6.8	0.22-0.27
Suey	12	24	6.0-6.5	0.17-0.22
East Huasna	17	30	6.2-6.7	0.15-0.19
Sur-Nacimiento	145	35	7.3-7.9	0.22-0.29
Rinconada	150+	39	7.3-7.7	0.20-0.25
South Cuyama-Ozena	50	42	6.9-7.5	0.16-0.21
La Panza	37	47	6.7-7.4	0.12-0.18
San Ynez-Pacifica	75+	47.5	7.1-7.6	0.14-0.19
Santa Lucia Bank	68±	67	7.0-7.6	0.09-0.13
San Andreas	600±	73	7.9-8.4	0.15-0.19

(*) From center of Guadalupe 7½ quadrangle.
(**) At center of Guadalupe 7½ quadrangle.

Fault lengths for this report were obtained from data presented in table 2. Dip of faults (60° to 90°) and focal depths (10 km) corresponding to maximum fault depth are assumed for the calculation of fault rupture area. Ranges of magnitude of MCE expected from faults are given in table 3.

6. Ground Shaking

Seismic waves propagate from sources of the disturbance in all directions (not necessarily with equal seismic wave amplitude). For engineering applications, one is concerned with strong motion experience in the near-field region, which is dominated by high frequency waves. In general, seismic waves are attenuated (diminished) by both elapsed time and distance from the source. Attenuation with distance is called spatial attenuation and depends primarily upon the physical properties of the propagating medium.

Several studies (for example, Trifunac, 1976; Boore et al., 1980) relate magnitude of earthquake, distance from seismic sources, and ground shaking induced by seismic waves. Due to lack of recorded data, there are widely differing opinions about ground shaking within a few kilometers from the seismic sources.

For the present site, we may apply the attenuation curves suggested by Schnabel and Seed(1973) because their study was directed to acceleration in rock from earthquakes in the Western United States. The bedrock accelerations are shown in table 3 and range from about 0.09 g (Santa Lucia Bank fault) to 0.73 g (Pezzoni-Casmalia-Los Alamos-Baseline fault). These accelerations are estimated for the center of Guadalupe 7 1/2' quadrangle.

7. Slope Instability

Three categories of areas of slope instability are portrayed on plates 1a and 2a. They include: (1) areas of active sand dunes; (2) areas of Quaternary landslides; (3) areas of steep river bank slopes and of recognized sea cliff instability.

Areas of active sand dunes are defined as those regions covered with unvegetated wind blown sand. These areas were compiled from topographic maps of the region and confirmed through aerial photo and field examination. Areas designated as Quaternary landslides were taken from the 1:24,000 geologic mapping of Woodring and Bramlette (1950) and confirmed from examination of aerial photos. One small area of steep river bank slope was defined from closely spaced contour lines and confirmed by aerial photo and field examination. The area designated as unstable sea cliffs was subjectively defined in a similar manner.

8. Seismically Induced Liquefaction

Major landslides, lateral movement of bridge supports, settling and tilting of buildings and failure of waterfront retaining structures have all been observed in recent years as a result of seismically induced liquefaction. As discussed in this report, liquefaction describes a phenomenon in which cohesionless sediments lose strength during an earthquake and acquire a degree of mobility sufficient to permit movements of several meters or more. Three criteria are needed to produce the phenomenon: (1) water saturation, (2) well- sorted, cohesionless sand or silt-size sediments, and (3) an earthquake. This is necessarily a somewhat simplistic explanation, but will suffice for the purpose of recognizing where this hazard has a potential of occurring. When an actual site is chosen, parameters such as grain size, sorting, relative density, thickness of strata, confining pressure and recurrence intervals of critical durations of earthquake stress cycles, could be obtained to better predict the likelihood of liquefaction.

In designating regions of the Point Sal and Guadalupe 7 1/2' Quadrangles where liquefaction may occur, the following assumptions and methods were used:

a. The region is seismically active and earthquakes of sufficient magnitude and duration of ground shaking will occur in the future. These earthquakes would induce liquefaction in appropriate soil conditions.

b. These soil conditions occur in non-indurated, well-sorted, sandy and silty sand units, as described on the geologic maps of Woodring and Bramlette (1950).

c. Liquefaction could only occur if these sediments were in a saturated condition below the water table.

d. Liquefaction would probably not occur at a depth greater than 18 meters, due to high confining pressure below this depth.

Using these relatively conservative assumptions, areas of "Old, Intermediate and Modern dunes sand and Alluvium" (Woodring and Bramlette, 1950), where the water table is less than 18 m from the surface (Cummings et al., 1970, and personal communication, 1980) have been designated as regions where liquefaction potential exists.

As with the previous sections of this report, we have been guided by the philosophy that it is prudent to include all areas where a potential hazard exists. In general, the liquefaction potential would increase in the westerly portions of the quadrangles (shown on plates 1a and 2a) because of both the shallower ground water table (Cummings et al., 1970 and DWR, 1980, pers. com.) and the increase in the silt and fine sand fraction of the alluvium in this region (Worts, 1951).

9. Flood Inundation

The Santa Maria River and its major tributaries, the Cuyama and Sisquoc Rivers, have a total drainage area of approximately 4300 square kilometers. This river system is the principal flood hazard to the area of study. The area drained is elongated in an east-west direction. The topographic highs which separate this basin from adjacent drainages include the Caliente Range, the La Panza Range, and Garcia Mountain on the north; and the Casmalia Hills, the Solomon Hills, the San Rafael Mountains, Big Pine Mountain, Pine Mountain, and San Guillermo Mountain on the south.

The flood hazard for the Guadalupe and Point Sal Quadrangles has been assessed using published estimates of three hypothetical floods. First is the 100-year probable flood. Data for this event were transferred to the Guadalupe 7 1/2' Quadrangle (plate 1b, item 1) from the same scale map prepared by the U.S. Geological Survey (1971). This hazard was omitted on the Point Sal Quadrangle because of the lack of a published source of data.

This event is delineated through the use of readily available information on past floods rather than from detailed field surveys and inspections. In the case of the Guadalupe 7 1/2' Quadrangle, portrayal of this flood assumes the flood control levees along the Santa Maria River remain intact.

A second hypothetical flood is the case of the 100-year flood, combined with levee failure of the flood control levees along the Santa Maria River (shown on plate 1b as item 2). The data for this event were obtained from the same source (U.S. Geological Survey, 1971), using available historic flood records. Portrayal of this hazard was, likewise, omitted on the Point Sal Quadrangle because of lack of a published source of data.

The flooded area caused by a third hypothetical flood, a catastrophic failure of the Twitchell Reservoir Dam on the Cuyama River, is depicted on plates 1b & 2b. This map was prepared in 1975 by the Water and Power Resources Service (former Bureau of Reclamation), and is available from the California Office of Emergency Services. The area of this potential flood, assuming a full reservoir and rapid failure, is shown on plates 1b and 2b as item 3. Lines of the estimated time, elapsed from the time of failure to the time of maximum water surface elevation, are shown on the maps. Both, the travel time and the elevation of the water surface would change appreciably with any variation in assumptions related to mode of dam failure. The following assumptions were made by the Water and Power Resources Service:

a. The reservoir would be full,
b. Twitchell Dam would be breached at the deepest point,
c. The breach would take the form of a steep sided parabola,
d. The breach would erode to near streambed in the time it would take for the reservoir to lose one-half of its volume,
e. Maximum discharge would be produced when the reservoir loses one-half of its volume, and
f. Potentially damaging downstream flow equals 2832 m^3/s.

10. Tsunami Hazard

Hazards from tsunami inundation are difficult to assess for the Point Sal area because of the short historical record and the lack of definitive literature on this subject. At least five tsunamis (with a probable runup $\geq$ 1.0 m) have occurred in this region since 1812. They include: 1812 (local generation), 1927 (local generation), 1946 (Aleutian trench generation), 1960 (Chile-Peru trench generation), and 1964 (Gulf of Alaska generation). The 1812 event is documented only from reports from early Spanish missions, and the precise amount of runup for this event is not known, but it is generally considered to be major. The 1927 tsunami produced a 1.8 meter wave at both Pismo and Surf (27 km north and 23 km south of Point Sal, respectively). The 1946 tsunami produced a runup of 1.2-1.5 m in San Luis Obispo Bay (Pismo?). The 1960 Chilean and the 1964 Alaskan earthquakes likewise produced tsunamis that reached the Point Sal region of the California coast. No runup data was found specifically for Point Sal, nor was any damage for the Point Sal area reported for any of these tsunamis. This is best explained by the fact that there has never been any significant population of settlers in this region.

A recent study by Houston and Garcia (1978) represents the state-of-the- art in assessing the 100-and 500-year probable (distant source) tsunami runup. This study includes the Point Sal region of the California Coast. Their calculated runup values include the effects of astronomical high tide and the shoreline configuration. Their results compare well with the variations in the runup for the different locations on the California coast observed in the 1964 tsunami. Their values for the 100-year and 500-year tsunami runup are shown on plate 2b and as item 4. These values do not include meteorological high tide (storm surge) nor storm waves, so a tsunami that arrived during a once-per-year storm would probably have additional height. Assuming 0.3± m storm surge and 3.8 m storm wave height, similar to that projected for Diablo Canyon Nuclear Power Plant by Earth Sciences Associates, 1974, this addition would yield a total wave height of 4± m.

An important information gap exists in this assessment of tsunami hazard, in that only distant source tsunami recurrence and runup values were calculated by Houston and Garcia (1978). Of the five historic tsunamis of probable wave height greater than 1 meter known to have occurred, only three were of distant origin. Both of the two tsunamis of local origin were higher in runup than the three distant source tsunamis.

It appears that locally generated tsunamis present a greater hazard to the area of this study than distant source tsunamis. Hammack (1972) has shown that near the generation area of a tsunami, details of ground motion during the earthquake and details of the permanent deformation of the seafloor influence the form of the resulting tsunami. According to Houston and Garcia (1978), "accurate predictions of the properties of locally generated tsunamis are not possible at this time". For the present study, no attempt was made to predict the precise runup hazard from a locally generated tsunami. The offshore extension of the Pezzoni-Casamalia-Los Alamos-Baseline fault because of its apparent activity, sense of movement, and location relative to the area of investigation, is a prime candidate for such an investigation.

In spite of Houston and Garcia's negative assessment of reliability of such studies, some hazard assessments have been made in this area. Earth Science Associates (1974), in studies done for the Diablo Canyon Nuclear Power Plant, have presented a detailed analysis of locally generated tsunamis for the Diablo Canyon area. A 9.14 m design basis sea water flood level was accepted by the NRC (1976).

II. SELECTED MINERAL AND GEOLOGIC RESOURCES

1. Fossil Fuel Production

The Guadalupe and Point Sal Quadrangles lie entirely within the well-explored and highly productive Santa Maria oil province (figure 4). In 1971, it was estimated that 100-600 million barrels of oil still remain to be found in the province mostly in the central area and near the northern and northeastern provincial borders (Crawford, 1971). Most of this oil is expected to be produced from already discovered fields, as no significant fields have been discovered since 1952 (Crawford, 1971; DOG, oral communication, 1980).

Some of the reasons why commercial oil fields have been considered potentially in conflict with the siting of other facilities include:

a. The fire hazard associated with oil producing operations.

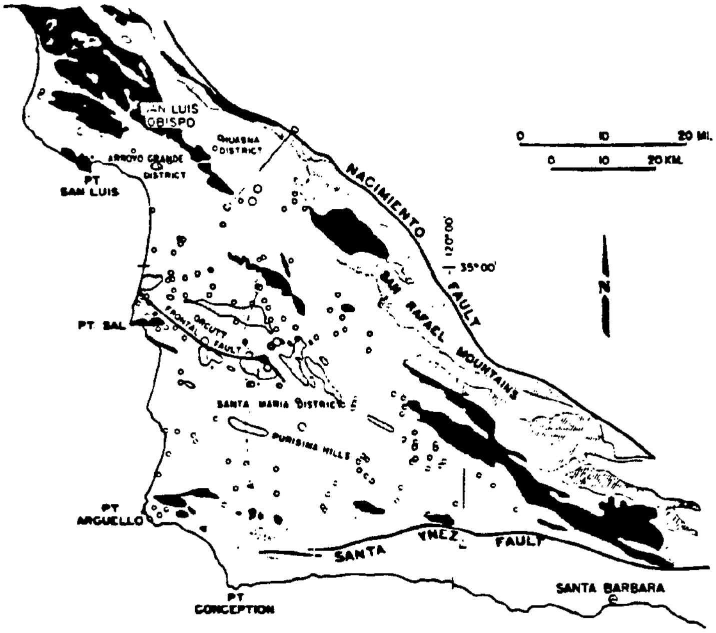


Figure 4

MAP SHOWING COMMERCIAL OIL FIELDS
OF THE SANTA MARIA PROVINCE

Vertically hachured areas are oil fields; solid black areas Jurassic - Lower Cretaceous outcrops; open circles are wells that penetrated "effective basement." (From Crawford, 1971)

b. Differential settlement and the potential reactivation of faults due to fluid withdrawal associated with oil production.

c. Induced seismicity associated with secondary recovery methods such as steam injection (usually micro-seismicity when compared to the regional seismicity of this province).

d. The loss of petroleum resources if production is stopped to mitigate the previous three problems.

All of these potential reasons for conflict are directly associated with the oil fields and are not regional in their effect. Severe settlement problems, such as those that have occurred in the area of Long Beach, have not been reported in the literature for this area. This could be due to lack of study of this problem in the Santa Maria Province. Secondary recovery methods using steam injection are being used in the fields on the Guadalupe and Point Sal Quadrangles (DOG, oral communication, 1980, and field observation).

Areas of known present day fossil fuel production are shown on plates 1a and 2a as item 6.

2. Ground Water Recharge

The entire study area, especially the Santa Maria Valley, is devoted primarily to agricultural use. 37% of this land within the Coastal Zone on the Guadalupe 7 1/2'Quadrangle is irrigated, presumably by ground water. Because of this, ground water becomes a very valuable mineral resource. According to hydrologic studies (Cummings et al., 1970), the

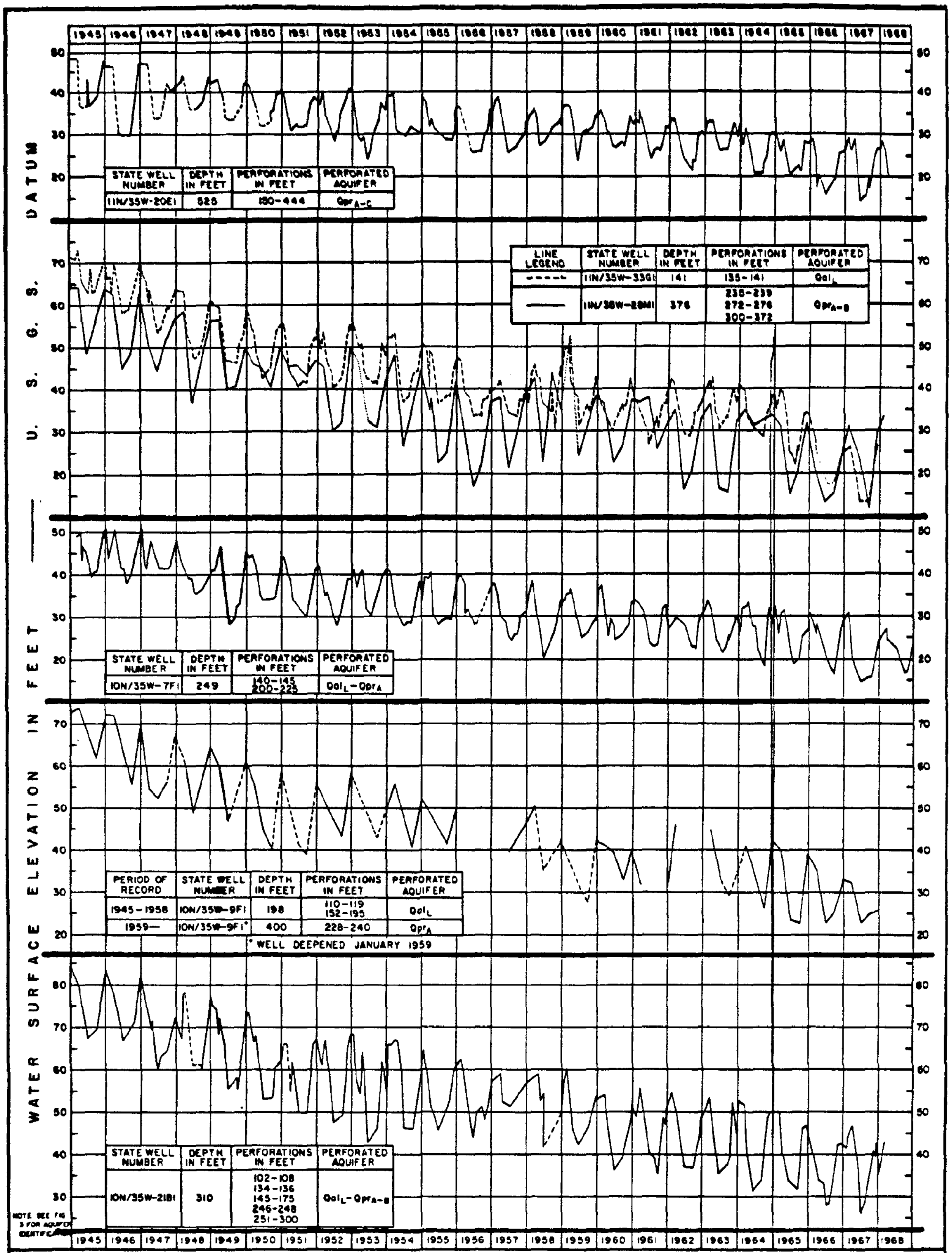


Figure 5. HYDROGRAPHS OF WATER LEVEL IN WELLS-
SANTA MARIA HYDROLOGIC SUBUNIT

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1969

(after Cummings, et al., 1970)

area north of the Casmalia Hills, in the Guadalupe Quadrangle, is part of the Santa Maria hydrologic subunit.

There are already problems in this hydrologic system - ground water level decline and salt water intrusion. Water level measurements in wells from 1945-1968 (Cummings et al., 1970) show a decline in the ground water level of this aquifer subunit (figure 5). The cause of this decline is considered to be the heavy pumping for irrigation. Salt water encroachment is already beginning to be a problem. Increases in groundwater use or decreases in fresh water recharge to the system would allow greater encroachment.

The principal recharge of ground water to this aquifer system occurs at the surface outcrops of the Paso Robles Formation on the north flank of the Casamalia Hills. For this reason, the area of outcrop of the Paso Robles Formation on the Guadalupe 7 1/2' Quadrangle has been portrayed as a valuable geologic resource on Plate 1b (Item 5). As the quantity and quality of the groundwater in this hydrologic subunit decreases, the value of this mineral resource will increase due to an assumed constant or increasing demand for water in this agricultural region.

Any major development in this region should require further study of the impacts by a hydrologist. The hydrology of the region has been studied by Cummings et al, 1970 and is being monitored by the California Department of Water Resources.

3. Diatomite Deposits

Portions of the Guadalupe 7 1/2' Quadrangle contain extensive deposits of commercial quality diatomite. Based on the assumption that any high value non-renewable mineral resource could be considered a constraint on other use of the property, areas of diatomite deposits are designated on plate la as item 7.

More information on these deposits is available in a recent article by Clark (1978). California, for many years, has been the largest producer of diatomite, supplying approximately 60% of the total production in the United States. Western Santa Barbara County contains the most extensive known deposits of high-quality marine diatomite in the world. Diatomite and bituminous diatomaceous shale have been mined in the Casmalia Hills (Guadalupe Quadrangle) at the Airox Corporation, NTU, and Waldorf Mines. These deposits were mined both for diatomite products and for petroleum by-products.

Extensive building on top of a valuable, or potentially valuable, non- renewable mineral resource can effectively eliminate that resource as a mineable commodity. Such a land use policy can lead to future shortages, higher prices, and potential elimination of the commodity. In this respect, the potentially mineable diatomite resources are designated on plate la as item 7 as a geologic element significant to planning.

In addition to the constraining aspects (loss of mineral resources), some of the diatomaceous deposits of this region can be considered a positive factor in the siting of certain facilities. The location of the Casmalia Class I disposal site on the adjoining Casmalia quadrangle is such a case. Here, the absorptive, filtering and impermeable nature of a diatomaceous porcelaneous mudstone are positive factors in the selection of a site as a storage dump for highly toxic waste materials. The nature of the Todos Santos Claystone member of the Sisquoc Formation as described and shown on the map of Woodring and Bramlette (1950), in general, shows these absorption, filtering, and impermeable characteristics. This deposit extends onto the Guadalupe Quadrangle in the south central portion adjacent to the purer diatomite shown as item 7 on plate 1a. To avoid confusion, the claystone unit has not been separately designated on the hazard/constraint maps but is well illustrated at the same scale on Plate 1 of Woodring and Bramlette (1950).

4. Unique Geologic Features

Many unique geologic features can be found in the area of the Point Sal and Guadalupe 7.5' Quadrangles. A few of these features have been subjectively selected as important enough to be considered in regional planning (plates 1a and 2a, items 8a-j). The features depicted are considered by the authors of this report to represent a unique geologic feature of significant scientific and/or educational value. All of the features selected have been described in the literature and are used by teachers, students, and professional geologists for educational field trips. Only geologic criteria were used in selection though some of the areas also contain botanical, archeological, zoological, recreational, and scenic values.

Several of the features designated are unique fossil occurrences, but not all fossil sites have been designated as unique. In fact, only a few of the more than 46 fossil localities described by Woodring and Bramlette (1950) for the subject quadrangles were classified in this report as unique geologic features. Criteria such as: species diversity, quality of preservation, accessibility for study, species type localities, number of literature citings, uniqueness of the fossil assemblage, and importance to stratigraphic definitions were subjectively weighed in choosing the fossil localities that have been put on plates 1a and 2a. The value of these localities is hard to estimate, but would include the fact that they constitute the principal basis for regional correlation and age dating of stratigraphic units within the Santa Maria basin, and to a lesser extent, the world. They have value as natural educational exhibits and sources of material for paleontological research. Section 6222, Part 1, Title 14, of the California Penal Code, which is commonly thought to protect fossil localities, though possibly applicable to these sites does not appear to protect them adequately from destruction.

Individual features occuring in the Guadalupe and Point Sal Quadrangles are described below:

Plate 1a

Plate 2a

Number	Quadrangle	Significance of Feature
8a	Guadalupe	The area, shown on Plate 1a, encompasses three fossil assemblage sites as described by Woodring and Bramlette (1950). All three contain abundant mollusc specimens and all three have been assigned permanent United States Geological Survey locality numbers (14934, 14896, and 14608) registered in the Cenozoic Invertebrate Register. Locality 14609 appears to be the type locality for the gastropod species <u>Bittium</u> <u>casmaliense</u> (Bartsach, 1911). About 40 molluscan species were identified from this area by W.P. Woodring and Bramlette, 1950).
8b	Guadalupe	Area 8b, as shown on Plate 1a, constitutes a well known and described complete section of the Pliocene Foxen Mudstone (Woodring and Bramlette, 1950). The section contains several fossiliferous strata and has a total thickness of 175 meters. One of the fossiliferous beds has been assigned a permanent

		U.S. Geological Survey locality number (14877) registered in the Cenozoic Invertebrate Register. 27 species of benthic Foraminifera and 5 species of molluscs have been identified as occurring in this section by Woodring and Bramlette (1950).
8c	Guadalupe	Area 8c, as shown on Plate la, is a rare fresh water gastropod fossil locality in the Plio-Pleistocene Paso Robles Formation. The locality has been described by Woodring and Bramlette (1950) and has been assigned a permanent U.S. Geological Survey locality number (14887) registered in the Cenozoic Invertebrate Register.
8d	Guadalupe	Area 8d, as shown on Plate la, is the mine dump of the abandoned Waldorf asphalt mine. The mine started operation before the turn of the century and is shown on a map by Eldridge (1901). The site is a very important fossil locality in the Pliocene Foxen Mudstone and has been extensively collected and described in the literature by Dall (1903), Arnold (1907), Bartsch (1911), Carson (1926), and Woodring and Bramlette (1950). In the latter report, the locality is described in the following manner: "The dump is an important locality, not only because of the large number of well preserved fossils, the exceptional preservation of which is due principally to

impregnation with asphalt, but also because it is the type locality of five forms: *Nassa waldorfensis*, *Ocinebra micheli* var. *waldorfensis*, *Drillia waldorfensis*, *Leda orcutti*, and *Venericardia californica*. More than three quarters of the known Foxen fauna is recorded only from this locality". The site has been assigned two permanent U.S. Geological Survey numbers (4473, 14879) registered in the Cenozoic Invertebrate Register.

8e Guadalupe Area 8e, as shown on plate 1a, is the site of the NTU Co. oil mine. The mine operated from 1923 to 1928. Based on tonnage mined and average grade of the deposit as estimated by Williams and Holmes (1945) and Gore (1923) it can be estimated that the NTU mine produced 27,000 bbls of oil. Williams and Holmes (1945) estimate that 100,000 bbls of oil are left in the part of the Sisquoc Formation actually visible in the NTU quarry. Fossils from the NTU mine site have been collected and described by Woodring and Bramlette (1950). They state: "Only two unusual localities", (within the basin facies of the Sisquoc Formation) "the NTU mine in the Casmalia Hills and the dump of the old Pennsylvania asphalt mine in the Orcutt field yielded more than 10 species" of molluscs. This site (the NTU mine) has yielded 16 species of molluscs and has been assigned a U.S. Geological Survey locality number (14878) registered in the Cenozoic Invertebrate Register.

8f Point Sal Area 8f, as shown on plate 2a, is the largest region designated in this category. The reasons for its scientific and educational significance are multiple. The sea cliff and canyon exposures include outcrops representing more than 100 million years of Santa Maria Basin stratigraphy. The exposures include: Franciscan Formation, Knoxville Formation, Lospe Formation, Point Sal Formation, Monterey Formation, Sisquoc Formation, Older and Modern dune sands (of Woodring and Bramlette, 1950), and at least three late Pleistocene marine terraces. These units are selectively complexly folded and faulted and contain classic exposures of a multitude of geologic structures that students and professionals of geology and natural history seldom see outside of the textbook. The section includes well exposed examples of normal and reverse faults, fault gouge, slickensides, drag folding, asphalt seeps, angular unconformities, disconformities, nonconformities, overturned bedding, cross bedding, graded bedding, fossil localities, anticlines, synclines, landslides, a well documented ophiolite sequence, gypsum and diatomite deposits, and even minor sulfide mineralization. The section exposed along the sea cliff and Mussel Rock Creek Canyon constitutes a unique outdoor classroom for structural, petroleum, and general geology students. This area has been used for educational field trips by organizations as diverse as the Geological Society of America, Mobil Oil Corporation, and California Polytechnic State University. A unique section of exhumed marine terrace topography is exposed in the lowest 0.5 km of Mussel Rock Creek Canyon. At least three Late Pleistocene terraces are well exposed in an exhumed topographic setting caused by erosion of modern and older dune sand. The lowest wave cut terraces contain trace fossils of burrowing pelecypods. Carbon-14 analysis of mollusc shells collected from beach deposits at an approximate elevation of 10 m, lying above the lowest terrace, have yielded a preliminary age determination of 25,460± 470 years before present. (Kenneth Lajoie, personal communication, 1980). This strongly suggests an Oxygen-18 Stage 3 correlation for the youngest terrace, an unusual occurence for the California Coast. . At a locality approximately 100 m NW of the mouth of Mussel Rock Creek and an elevation of 30 meters an aboriginal kitchen midden site was discovered containing abundant *Mytilus californianus*. These shells are being Carbon-14 dated and probably are derived from the Chumash Indian village of Kasmali.

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STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION

PLATE 3
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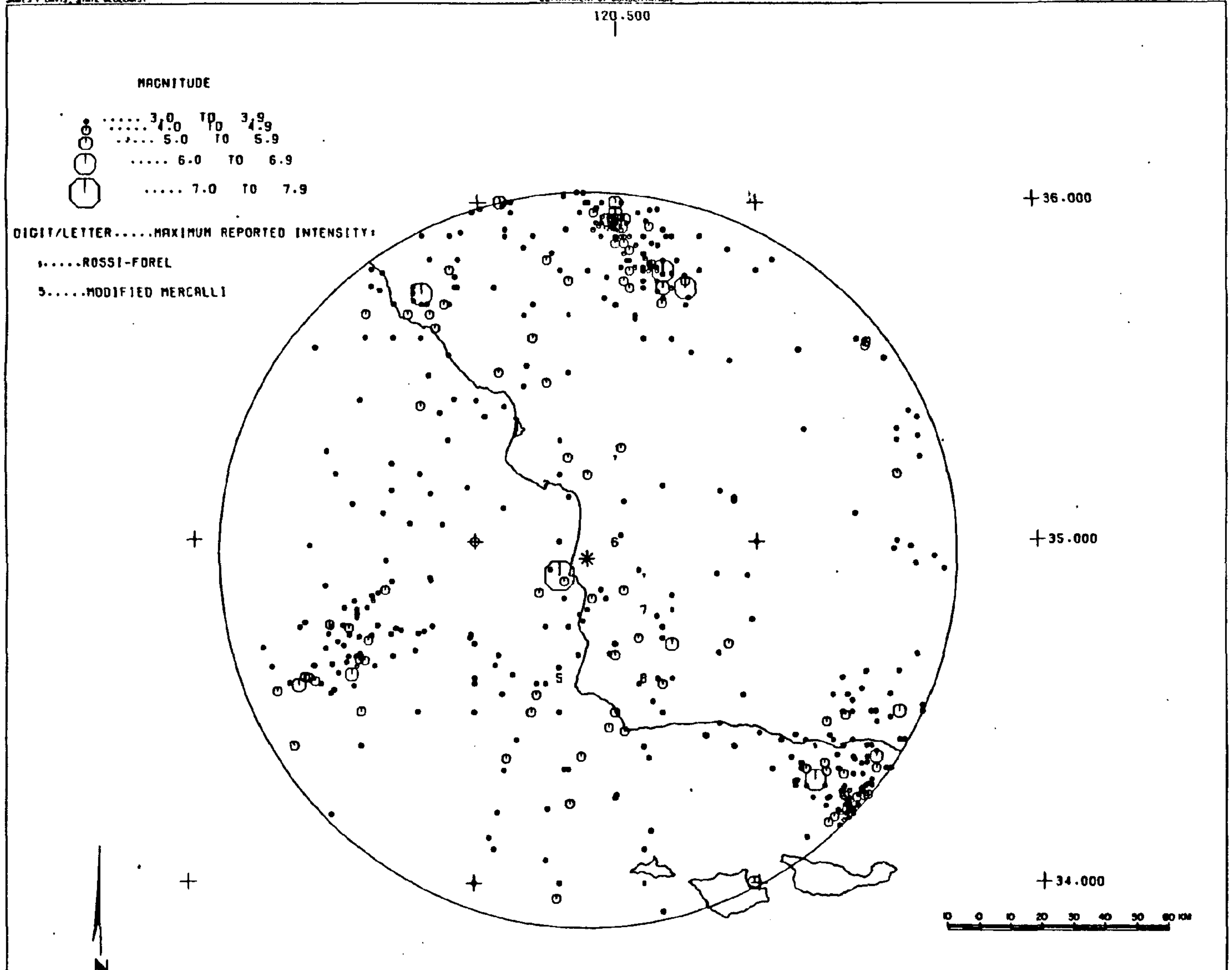

EPICENTER MAP OF EARTHQUAKES (M≥3) WITHIN 120KM OF THE CENTER OF THE USGS GUADALUPE 7 1/2' QUADRANGLE (1900-1975)