2.5C APPENDIX 2.5.C

SOIL BORINGS

A total of 41 onshore borings were drilled to depths ranging from 6 to 987 ft in the plant area of the San Onofre Nuclear Generating Station, Units 2 and 3. In addition, 11 offshore borings and Jet probes were made in the area of circulating water conduits to determine nearsurface seafloor soil conditions. Locations of all onshore borings in relation to the plant facilities are shown on Fig. 2.5.C.1. Locations of offshore borings and jet probes are shown on Figs. 2.5.C.2 and 2.5.C.3.

Borings were made by a variety of drilling techniques such as: rotary drilling, bucket auger, hollow-stem auger, jet probing, and vibracore. Both disturbed and intact samples were obtained during drilling by various techniques such as: Standard Penetration Test Method, Modified-California Sampler, Shelby Tubes, and Pitcher Barrel Sampler. In addition to sampling during drilling, a number of intact, hand-carved block samples were obtained for comparison testing to evaluate sample disturbance effects of conventional sampling techniques.

Details concerning various investigations, including title and date of original report, number and depth of borings, type of drilling and sampling and PSAR/FSAR sections where the data can be found are summarized in Table 2.S.C.1.

TABLE 2.5.C.1
SUMMARY OF DRILLING AND SAMPLING

Original Report Title and Date	Borings	No. of Range, ft	Depth Drill Rig	Type of Sampling	Where Data Reported
Seismic and Foundation Studies, Proposed Units 2 and 3, San Onofre Nuclear Generating Station, 15 Apr 70, Dames & Moore	4	55-987	Bucket and rotary	Pitcher barrel and Dames & Moore underwater sampler	San Onofre Nuclear Generating Station Units 2 and 3, Amendment No. 1 to PSAR, 31 Aug 70, Appendix 2B
Continuous Seismic Profiling Investigation of the Continental Shelf off San Onofre, CA 24 Apr 70, Marine Advisors Inc. Solana Beach, CA	4 (offshore)	10-22	Jet probe	None	SONGS Units 2 and 3, Amendment No. 1 to PSAR 31 Aug 70, Appendix 2B
Material Property Studies San Onofre Nuclear Generating Station March 13, 1972 Woodward-McNeill & Assoc.	7	30-162	6-in. dia. rotary	Modified California Attachment 3.	SONGS Units 2 and 3, Amendment No. 11 to PSAR 1 Apr 72, Appendix 2E
Stability of Proposed slopes for the Proposed units 2 and 3, San Onofre Nuclear Generating Station, San Onofre CA, 27 Mar 73, Woodward-McNeill & Associates	7	40-300	5-in. dia. rotary	Modified California and Pitcher barrel sampler	SONGS Units 2 and 3, Amendment No. 17 to PSAR 18 Apr 73, Appendix 2H
Dynamic Switchyard Slope stability confirmation Proposed Units 2 and 3, San Onofre Nuclear Generating Station San Onofre CA, 18 Oct 74, Woodward-McNeill & Associates	13	35-80	5-in. dia. rotary and 6-in. dia	Pitcher barrel, Modified California and continuous flight	SONGS Units 2 and 3, FSAR Appendix 2.5.E shelby tube sampler
Offshore Liquefaction Evaluation for the Proposed Units 2 and 3, San Onofre Nuclear Generating Station San Onofre CA, 19 Dec 74, Woodward-McNeill & Associates	3 (onshore) 7 (offshore)	40-60 3-7	6-in. cont. flight auger and 5-in rotary	Modified California pitcher barrel and shelby tube sampler	SONGS Units 2 and 5, FSAR Appendix 2.5.A
Final report on Geologic Features at the San Onofre Nuclear Generating Station 5 Mar 76, Fugro, Inc.	7	6-25	Bucket auger	None	Submitted by letter, J. B. Moore to O. D. Parr Aug. 11, 1977

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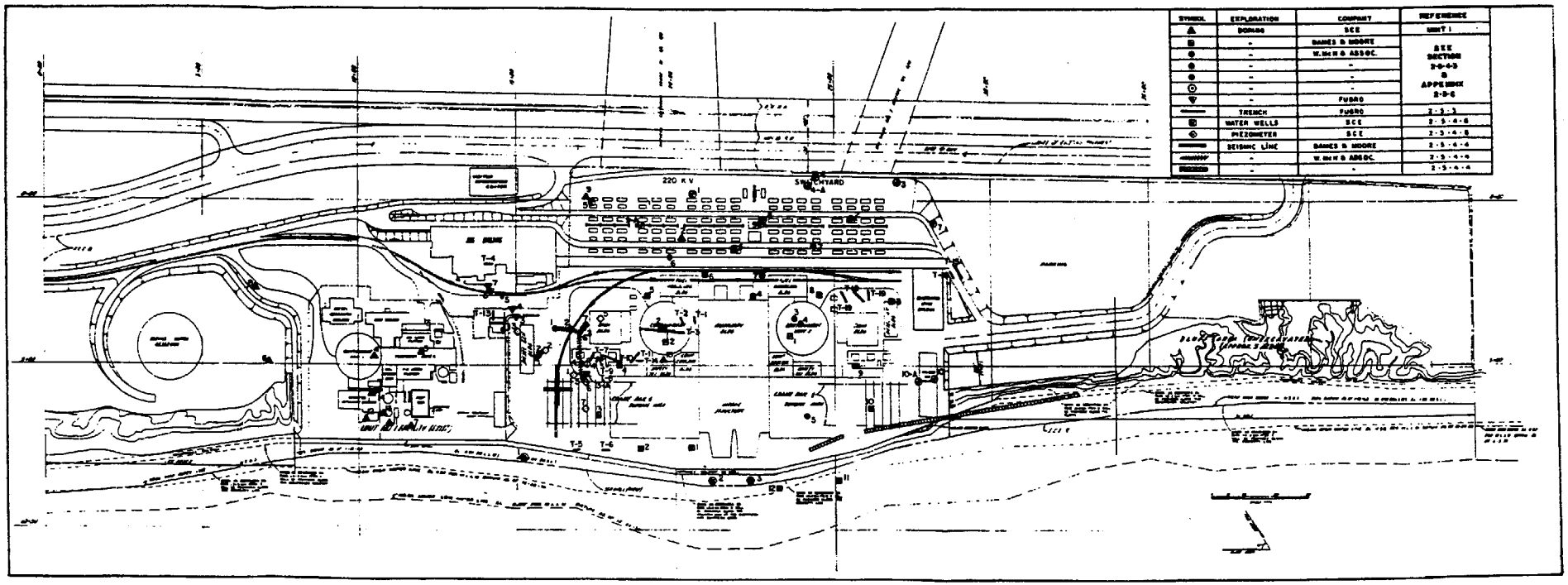
220 KV
SWITCHYARD
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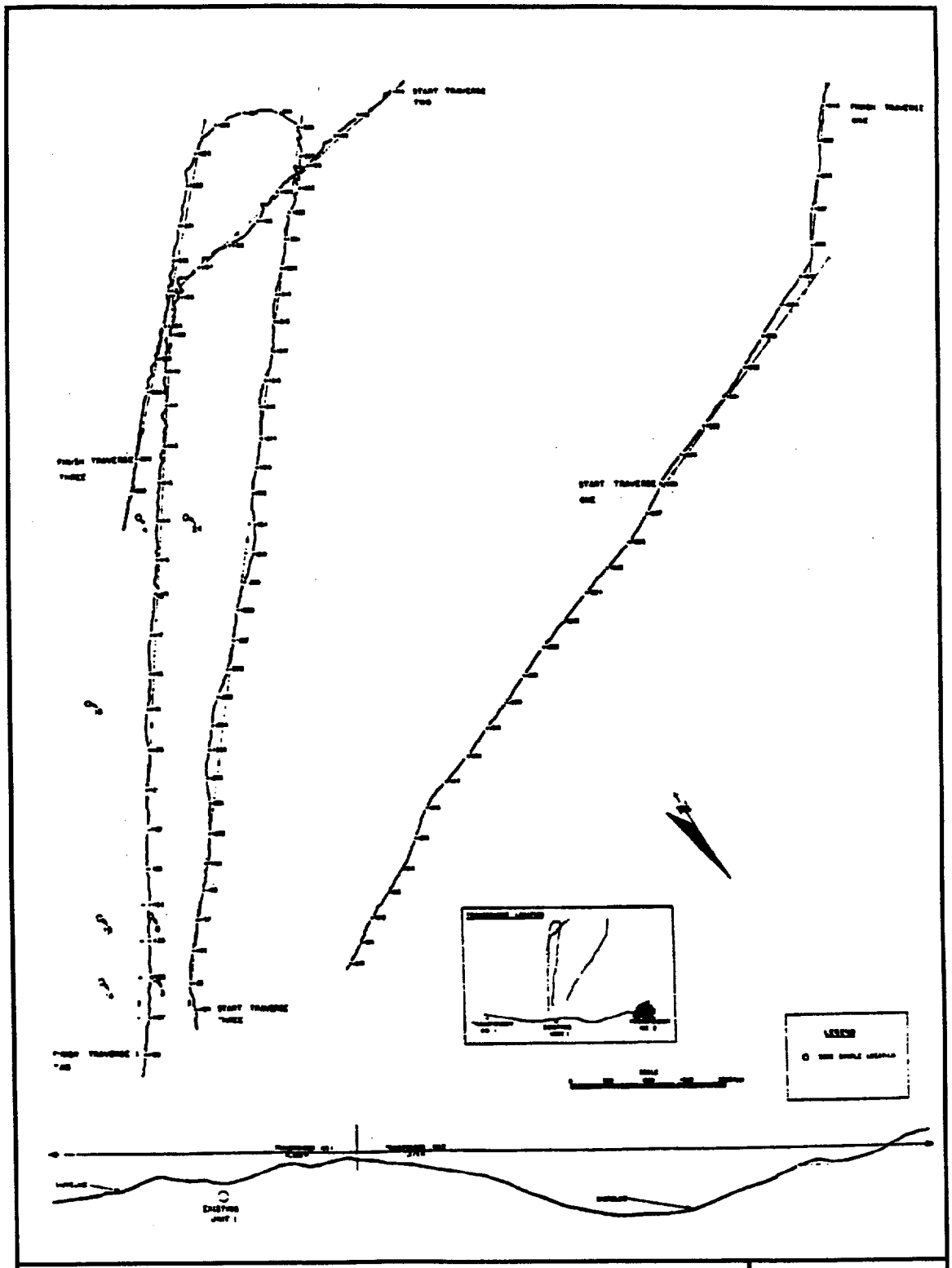

TRAVERSE FOR BOOMER SURVEY AND LOCATIONS FOR VIBROCORE SAMPLING	2.5.C.2

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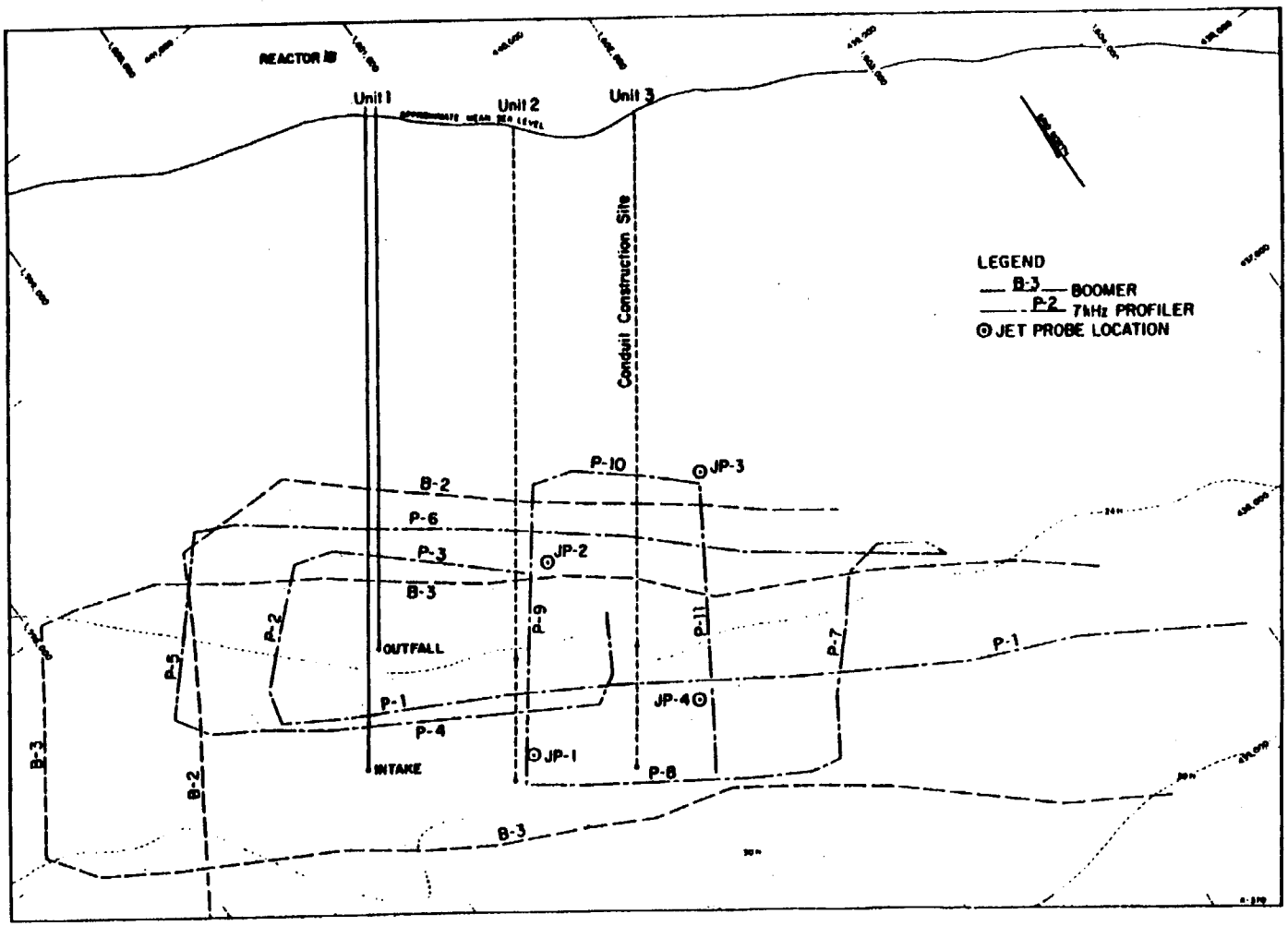

HIGH-RESOLUTION PROFILE LINES AND JET PROBE LOCATIONS IN VICINITY OF COOLING WATER CONDUIT CONSTRUCTION SITES.

2.5.C.3

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APPENDIX 2.5D

LABORATORY TESTING AND SOIL PROPERTY EVALUATION

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APPENDIX 2.5.D

LABORATORY TESTING AND SOIL PROPERTY EVALUATION

A total of 7 separate laboratory investigations were conducted for evaluating the soil properties at the San Onofre Nuclear Generating Station Units 2 and 3. Both static and dynamic testing was done to estimate soil parameters to be used in static stability studies and dynamic response and liquefaction analyses.

The total number and purpose of the more important tests are summarized in Table 2.5.D.1. Details concerning various investigations including title and date of original report, types of laboratory tests included in each investigation and PSAR/FSAR section reference where data can be found are summarized in Table 2.5.D.2.

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TABLE 2.5.D.1

LABORATORY TEST SUMMARY

TEST	PURPOSE	TOTAL NUMBER
Moisture/Density	--Classification and Identification	138
Grain-Size Analyses		147
Specific Gravity		83
X-ray diffraction		6
Chemical Analysis		4
Thin-section Examination		2
Field Density	Insitu Strength/Density	130
Compaction	Compaction Characteristics	6
Minimum/Maximum Density	Estimate Relative Density	2
Unconfined Compression	Static Strength	22
Triaxial Compression	Static Strength	32
Direct Shear	Static Strength	7
Strain-Controlled Dynamic Triaxial	Modulus and Damping parameters	47
Stress-Controlled Dynamic Triaxial	Liquefaction	131

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TABLE 2.5.D.2

SUMMARY OF LABORATORY INVESTIGATIONS

Original Report Title and Date	Type of Tests	Where Data Reported
Seismic and Foundation Studies, Proposed Units 2 and 3, San Onofre Nuclear Generating Station, 15 Apr 70, Dames & Moore	Moisture/Density, Grain size, Unconf. Compression, Triaxial Comp., Direct Shear, Dynamic Triaxial	San Onofre Nuclear Generating Station Units 2 and 3, Amendment No. I to PSAR 31 Aug 70, Appendix 2B.
Material Property Studies San Onofre Nuclear Generating Station, Woodward-McNeill & Associates, March 13, 1972	Moisture/Density, Grain Size, Unconf, Comp., Field density Max/Min density, Dynamic Triaxial	SONGS Units 2 and 3, Amendment No. 11 to PSAR, 1 Apr 72, Appendix 2E, Attachment 3.
Stability of Proposed Slopes for the Proposed Units 2 and 3, San Onofre Nuclear Generating Station, San Onofre, CA, 27 Mar 73, Woodward-McNeill & Associates	Grain Size, Unconf. Comp., Triaxial comp.	SONGS Units 2 and 3, Amendment No. 17 to PSAR, 18 Apr 73, Appendix 2H
Liquefaction Evaluation Report, Proposed Units 2 and 3, San Onofre Nuclear Generating Station, 22 Jan 74, Woodward-McNeill & Associates	Compaction, Dynamic Triaxial	SONGS Units 2 and 3, FSAR, Appendix 2.5.A
Dynamic Switchyard Slope Stability Confirmation, Proposed Units 2 and 3, San Onofre Nuclear Generating Station, San Onofre, CA, 18 Oct 74, Woodward-McNeill & Associates	Moisture Density, Grain Size Sp. Gravity, Unconf. Comp., Dynamic Triaxial	SONGS Units 2 and 3, FSAR, Appendix 2.5.E
Offshore Liquefaction Evaluation for the Proposed Units 2 and 3 San Onofre Nuclear Generating Station, San Onofre, CA 19 Dec 74, Woodward-McNeill & Associates	Grain Size, Field Density, Dynamic Triaxial	SONGS Units 2 and 3, FSAR, Appendix 2.5.A
Analyses of Properties of Finer-Grained San Mateo Sand, Units 2 and 3, 31 Dec 74, Woodward-McNeill & Associates	Grain Size, Sp. Gravity, Compaction, Static Triaxial, Dynamic Triaxial	Submitted by letter K. P. Baskin to O. O. Parr, November 12, 1976.

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APPENDIX 2.5E

DYNAMIC SWITCHYARD SLOPE STABILITY CONFIRMATION

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DYNAMIC SWITCHYARD SLOPE STABILITY CONFIRMATION PROPOSED UNITS 2 AND 3 SAN ONOFRE GENERATING STATION SAN ONOFRE, CALIFORNIA

for

Southern California Edison Company
P. O. Box 800
Rosemead, California 91770

by

WOODWARD-McNEILL & ASSOCIATES
Consulting Engineers and Geologists

2.5E-1/2.5E-2

Amended: April 2009 TL: E048000

Los Angeles
18 October 1974
Project No. B469A4

Southern California Edison Company
P. O. Box 800
Rosemead, California 91770

Attention: Mr. David H. Johns

SUBJECT : DYNAMIC SWITCHYARD SLOPE STABILITY CONFIRMATION
PROPOSED UNITS 2 AND 3
SAN ONOFRE GENERATING STATION
SAN ONOFRE, CALIFORNIA

Gentlemen:

In accordance with the provisions of your Purchase Order No. U0804901, we have completed our analyses of the dynamic stability of the proposed switchyard slopes at the subject site. The attached report transmits the results of our studies.

In brief, the results indicate that for DBE loading, the switchyard slopes will be stable, with localized surficial sloughing possible. Also, the analyses indicate that some lenses of material within the terrace deposit may become overstressed, however, it is not felt these will contribute to instability as they are not near any slope surface.

If you have any questions or require further information, please contact us at your convenience.

Very truly yours,

WOODWARD-McNEILL & ASSOCIATES

By John A. Barneich
John A. Barneich

By Robert L. McNeill
Robert L. McNeill

By Andrew M Worswick
Andrew M. Worswick

JAB:RLMcN:AMW:ls
Attachments

2.5E-3/2.5E-4

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DYNAMIC SWITCHYARD SLOPE STABILITY CONFIRMATION
PROPOSED UNITS 2 AND 3
SAN ONOFRE GENERATING STATION
SAN ONOFRE, CALIFORNIA

1.0 INTRODUCTION

In accordance with the provisions of our proposal dated 7 Nov 73, Item 1 of Amendment No. 19 to the Preliminary Safety Analysis Report, dated 25 Jul 73, and your Purchase Order No. U0804901, we have conducted a geotechnical investigation and provided consulting services for DBE Switchyard Slope Stability Confirmation, San Onofre Generating Station, Units 2 and 3, San Onofre, California. Previous analyses of the stability of the proposed switchyard slopes have been made, and are presented in our report entitled *Stability of the Proposed Slopes for the Proposed Units 2 and 3, San Onofre Generating Station, San Onofre, California,* dated 27 Mar 73. The purposes of the present studies are:

1) to supplement previous field investigations in determining the areal degree of saturation of terrace soils,

2) to collect and dynamically test selected samples of the critical (weakest) materials encountered during the field investigation, and

3) to perform analyses to evaluate dynamic stability of the proposed switchyard slopes.

These studies involved field and laboratory investigations, which are discussed in Appendicies A and B, respectively. Other factual data are presented in the appendicies as follows: Appendix C, Soil Properties; Appendix D, Finite-Element Studies; and Appendix E, Stability Evaluation. Appendix F presents a

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reference guide to aid the reader in locating specific items referenced in Amendment No. 19 to the PSAR.

A description of the proposed slope construction is presented in Section 2.0. Geotechnical conditions, interpreted from boring log information, air photos, inspection of site grading operations, and previous studies of the site, are discussed in Section 3.0. A discussion of the significance of these conditions as they relate to the proposed development, and our conclusions, are presented in Section 4.0. A summary of our conclusions is presented in Section 5.0.

2.0 DESCRIPTION OF SLOPE CONSTRUCTION

It is proposed to construct a series of slopes and benches between the proposed SONGS Units 2 and 3 plant grade (elev. 29 ft) and existing Highway 101 (approx. elev. 115 ft) for use as a switchyard. A site plan showing the proposed slopes is presented on Fig. 1. A cross-section through the proposed switchyard slopes is presented on Fig. 2. The slopes will be cut, as reflected by the difference between existing and final grade indicated on Fig. 2. Southern California Edison has indicated that the switchyard structures proposed for construction will be supported on shallow spread footings or drilled pier foundations. Southern California Edison has indicated that switchyard structures, including their foundations, will be designed such that their associated loads will not change the conclusions of the slope stability analyses.

3.0 GEOTECHNICAL CONDITIONS

3.1 General Site Conditions

The proposed site for Units 2 and 3 is located adjacent

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to and south of the existing Unit 1, as shown on the Site Plan, Fig. 1. At the present time the switchyard slope area has been graded. The upper slope has been cut to approximately the finished grade. The lower slope has been temporarily cut to an inclination of ½:1 (horizontal to vertical) to provide a larger working area for construction. This slope will be cut back to a finished 2:1 grade at a later date.

Prior to excavation for the plant site, near-vertical bluffs along the beach rose from sea level to approximately elevation 80 ft. From the top of these bluffs the natural ground surface rose gently toward the existing Highway 101. Photos showing the topography of the site in 1928 and 1972 are presented as Figs. 3 and 4, respectively. Fills were constructed in the proposed switchyard area, adjacent to Highway 101, during grading of Unit 1. These fills, which have been removed, provided an area for the Unit 1 switchyard and tourist center.

3.2 Subsurface Conditions

3.2.1 Soil Conditions

Boring log data (Appendix A), laboratory test results (Appendix B), information from previous studies, and data obtained from inspection of cut slopes excavated on the site, were considered in determining soil conditions. A schematic representation of the distribution of soils at the site is included in Fig. 2.

As indicated in Fig. 2 the upper portion of the switchyard slope consists of terrace deposit materials. These materials, which extend beneath the surface to

approximately elevation 50 ft, consist of very dense and very stiff soils. The upper portions of the terrace deposit (above approximately elev. 80 ft) are generally clayey sands to silty clays. These materials are underlain by predominately gravelly sand materials, with occasional lenses of clay, silt, and cobbles. The soils which constitute the base of the terrace deposit (approximately elev. 50 to 60 ft) are quite variable. In some areas coarse gravel and cobbles are present, while in others silty sand, sandy silt, or silty clay exists. These materials are underlain by the San Mateo Formation, which extends to approximately elev. -850 ft. This formation consists of a dense to very dense, well graded sand with apparent cohesion due to efficiency in packing. The borings made during this investigation indicate a slightly different distribution of soils than has been described in the PSAR, however, the dynamic strength of these materials appear to be as high or higher than previously assumed. A discussion of the pertinent soil properties used in the analyses is presented in Section 4.1.

3.2.2 Groundwater Conditions

No groundwater was observed in any of the borings made for this study. All boring-log data from previous studies indicate that no free groundwater was present above elev. 5 ft (MLLW Datum). Southern California Edison has indicated that piezometers on the site indicate the groundwater surface is at approximately elev. +5 ft.

4.0 DISCUSSION AND CONCLUSIONS

4.1 Soil Properties

4.1.1 Dynamic Strength

One of the primary purposes of this study was to define accurately the dynamic strength of the terrace deposit soils. To accomplish this an extensive laboratory testing program was performed. The details of this program, as well as other tests performed, are presented in Appendix B. In general, the results of the testing program indicate the terrace soils have strengths as high as, or higher than previously assumed. There do appear to be occasional thin lenses of weaker materials in the lower part of the terrace deposit which: 1) appear to be horizontally stratified, 2) are not continuous through the slopes, and 3) are generally less than 3 ft in thickness. Our analyses have considered the possibility that weak lenses exist throughout the sandy lower portion of the terrace deposit, as outlined in Appendix E. The interpreted strength curves for this material, as well as the others which are present in the profile, are presented in Appendix C. A summary of the interpreted strengths for all materials is presented in Fig. 5 for easy reference. These curves were drawn considering the lower bound of strength data to be defined at +5% strain or 10% total strain, whichever occurred first.

4.1.2 Dynamic Stiffness and Damping

The cyclic triaxial test data were analyzed in order

to estimate dynamic stiffness and damping properties of the terrace soils, as outlined in Appendix B. These data indicate the sandy portion of the terrace deposit are somewhat stiffer than previously assumed. This change was incorporated in the finite-element model for our studies. These data indicate that the damping assumed for this material during the previous studies was appropriate, as were the stiffness and damping values for the other soils at the site. The stiffness and damping properties used are presented in Appendix C.

4.2 Groundwater Conditions

Analyses were made of the areal degree of saturation of the terrace deposit soils, as outlined in Appendix C. A summary of the analysis of 79 samples is presented in Fig. 6. Figure 6 indicates that: 1) no samples tested were 100% saturated; 2) samples with a degree of saturation of greater than 70% were predominantly clayey; and 3) the average degree of saturation is approximately 50%. Southern California Edison has indicated that careful surficial drainage control for the site will be implemented, therefore no significant changes in groundwater conditions are anticipated.

4.3 Finite-Element Studies

In order to evaluate dynamic stability, a finite-element model of the slope-foundation system was developed. Static and dynamic computer programs were then used to estimate existing and earthquake-induced stresses throughout the profile. Details of the finite-element studies performed are presented

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in Appendix D. The output stresses from the finite-element programs were compared to the dynamic soil strengths (Appendix C) in order to evaluate dynamic stability.

4.4 Dynamic Stability Evaluation

Analyses were made to determine the number of equivalent equal significant stress applications induced in the soil profile by the DBE to facilitate comparison of induced stress to the dynamic soil strength. Details of these analyses are presented in Appendix E. Analyses were made assuming 1) the most likely soil conditions which exist (based on boring log data, examination of graded slopes, etc.), and 2) weak lenses are present throughout the lower portion of the terrace deposit. Based on the results of these analyses it is concluded that, during DBE loading, 1) the overall factor of safety of the switchyard slopes is in excess of 1.0, 2) surficial sloughing to a maximum depth of 5 ft may occur on the uppermost switchyard slope, and 3) overstressed zones may develop in localized portions of the terrace deposit. These zones are shown schematically on Fig. 7. Interpreted factors of safety of each finite element in the slope are presented on Fig. 8 (Factor of Safety is conservatively defined as the ratio of dynamic stress necessary to cause 10% strain for 80 stress applications to the corresponding seismic induced stress as detailed in Appendix E). It is our opinion that the overstressed zones will not cause instability because there are many stable areas between those which are overstressed and any free surface. Further, the soil strata are essentially

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horizontally stratified with stronger lenses interbedded with weaker ones. The 80 stress applications (consistent with the DBE synthetic time history) used in the present analysis was chosen to demonstrate the stability of the slopes when subjected to a very conservative seismic loading. As a comparison a more realistic number, one consistent with earthquake engineering practice for a single severe event (DBE-type), would be on the order of 30 cycles, or less than half the number used in the present analysis.

5.0 SUMMARY OF CONCLUSIONS

5.1 In general, the results of the testing program indicate the terrace soils have strengths as high as, or higher than previously assumed.

5.2 There appear to be occasional thin lenses of weaker materials in the lower part of the terrace deposit which: 1) are essentially horizontal; 2) are not continuous through the slopes; and, 3) are generally less than 3 ft in thickness.

5.3 Laboratory test results indicate that the dynamic stiffness and damping values used in the previous analyses were appropriate for the three primary site soils (i.e., terrace sands, terrace clays, and San Mateo Sand). The maximum deviation was exhibited by the terrace sands where the modulus was somewhat higher than previously assumed (approximately 12% maximum).

5.4 Extensive laboratory testing indicates that the terrace soils in the subject area are only partially saturated, with an average degree of saturation of approximately 50%.

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5.5 Our analyses indicate that during DBE loading: 1) the overall factor of safety of the switchyard slopes is in excess of 1.0; 2) surficial sloughing to a maximum depth of 5 ft may occur on the uppermost switchyard slope; and 3) overstressed zones may develop in localized portions of the terrace deposit. It is our opinion that the overstressed zones are unlikely to lead to instability, as discussed in Section 4.4.

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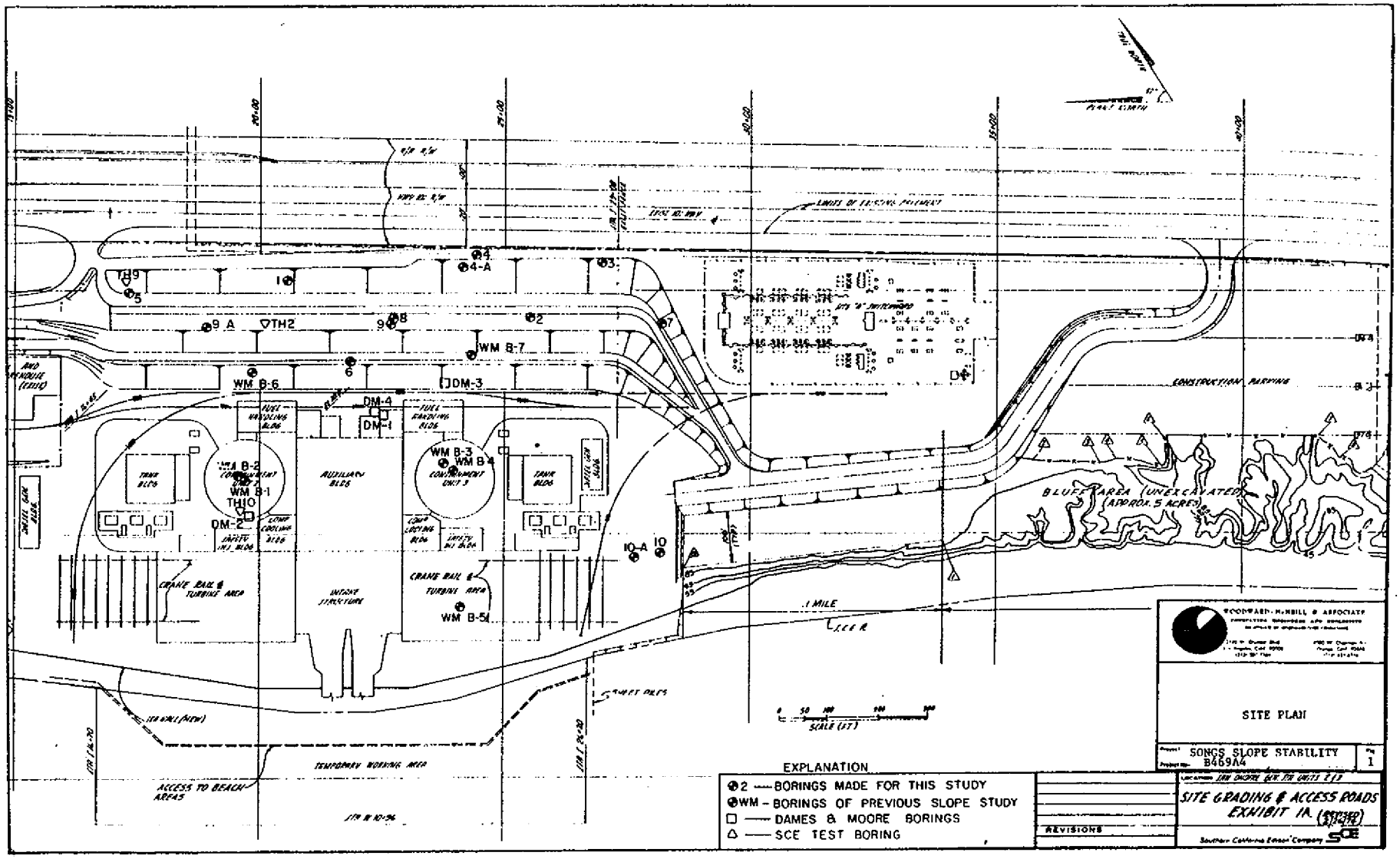

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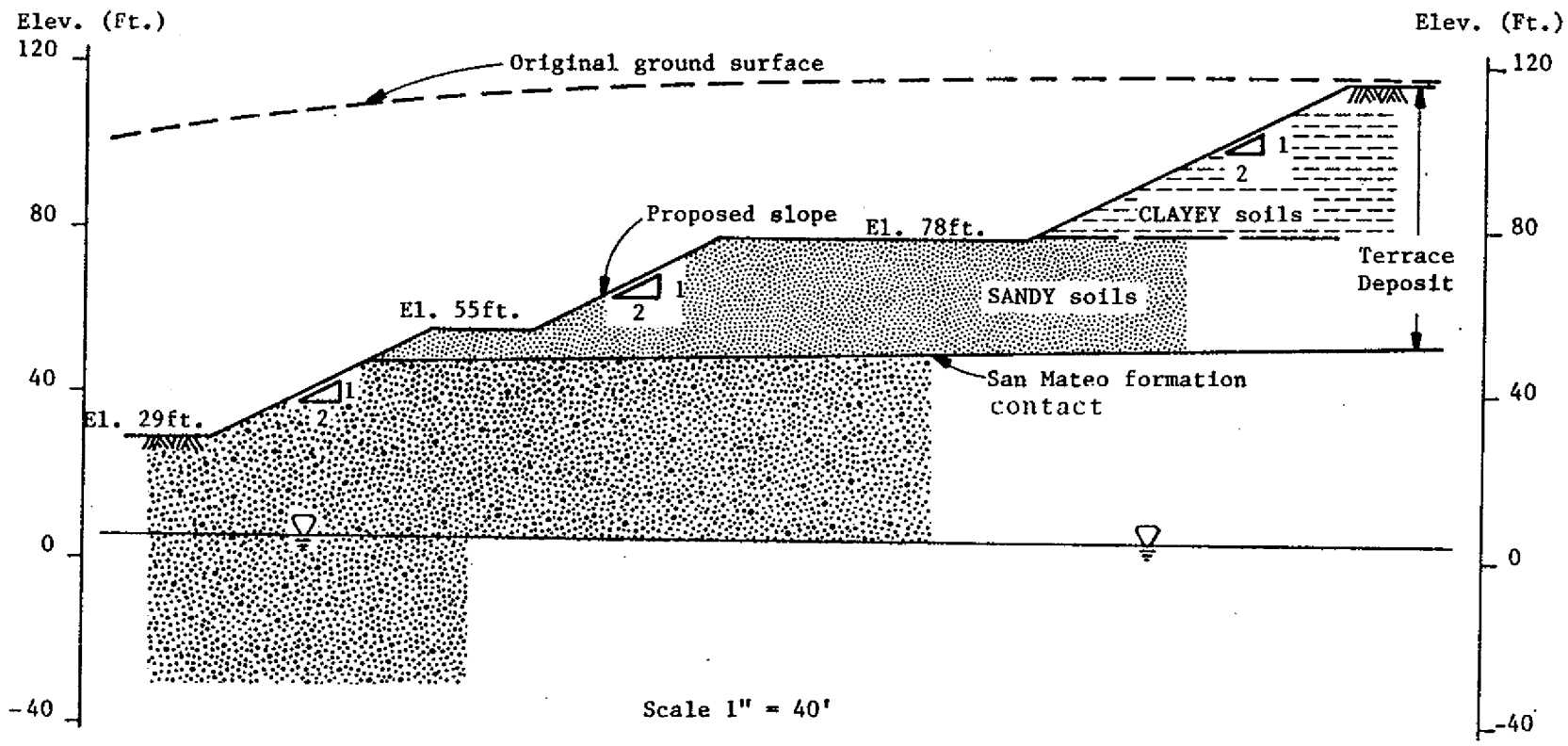
Job Number: B469A4

SECTION OF PROPOSED SWITCHYARD SLOPES

Fig. 2



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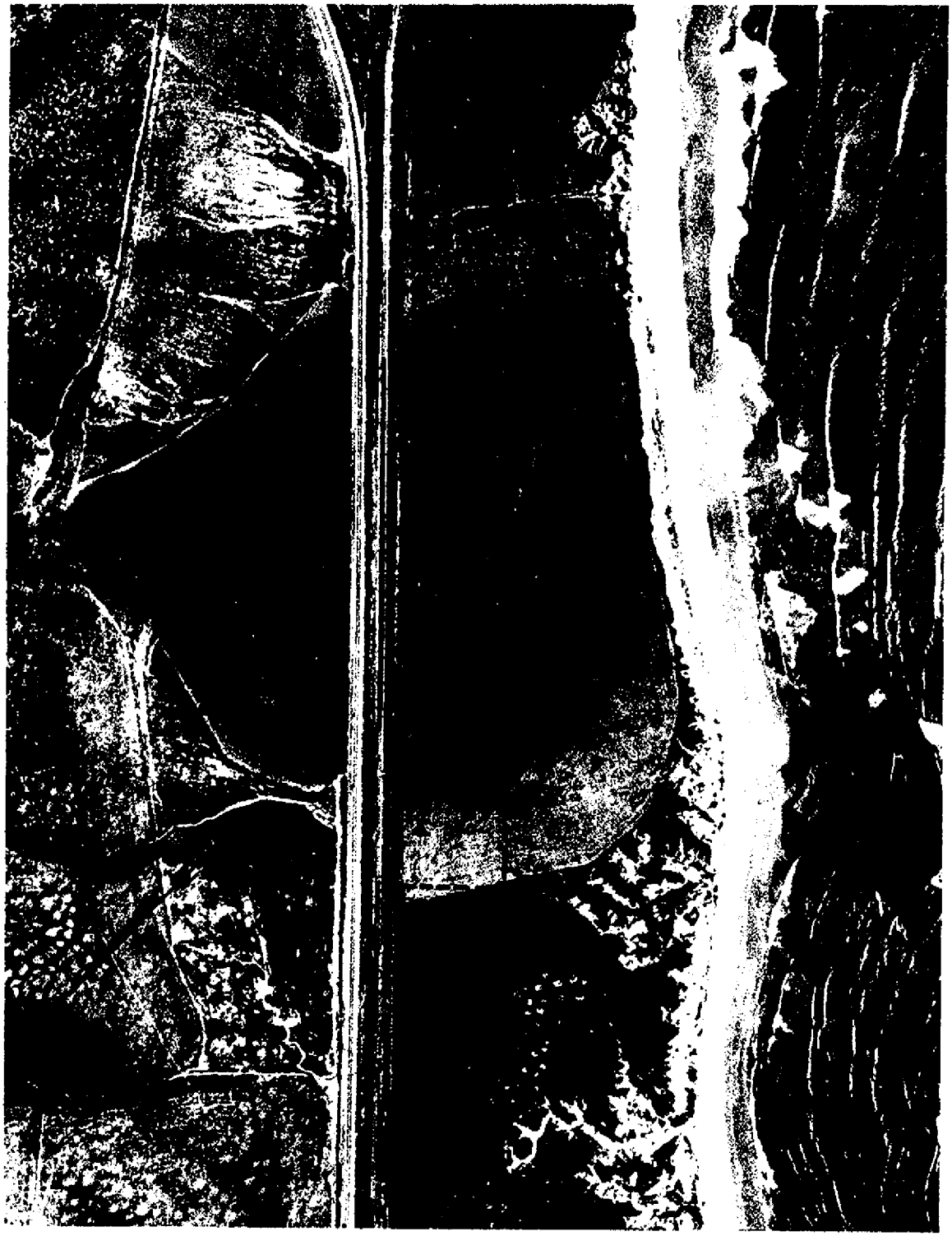
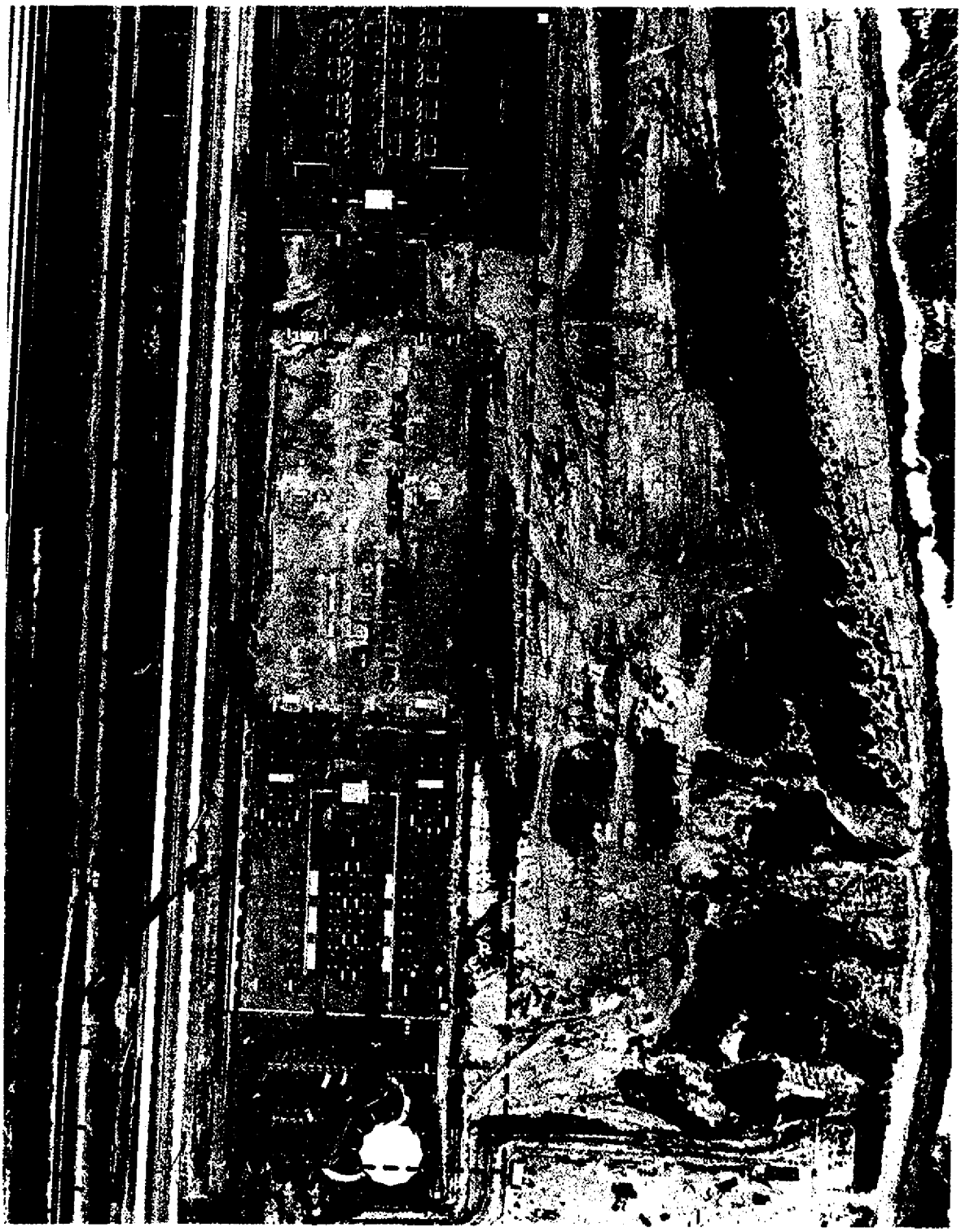
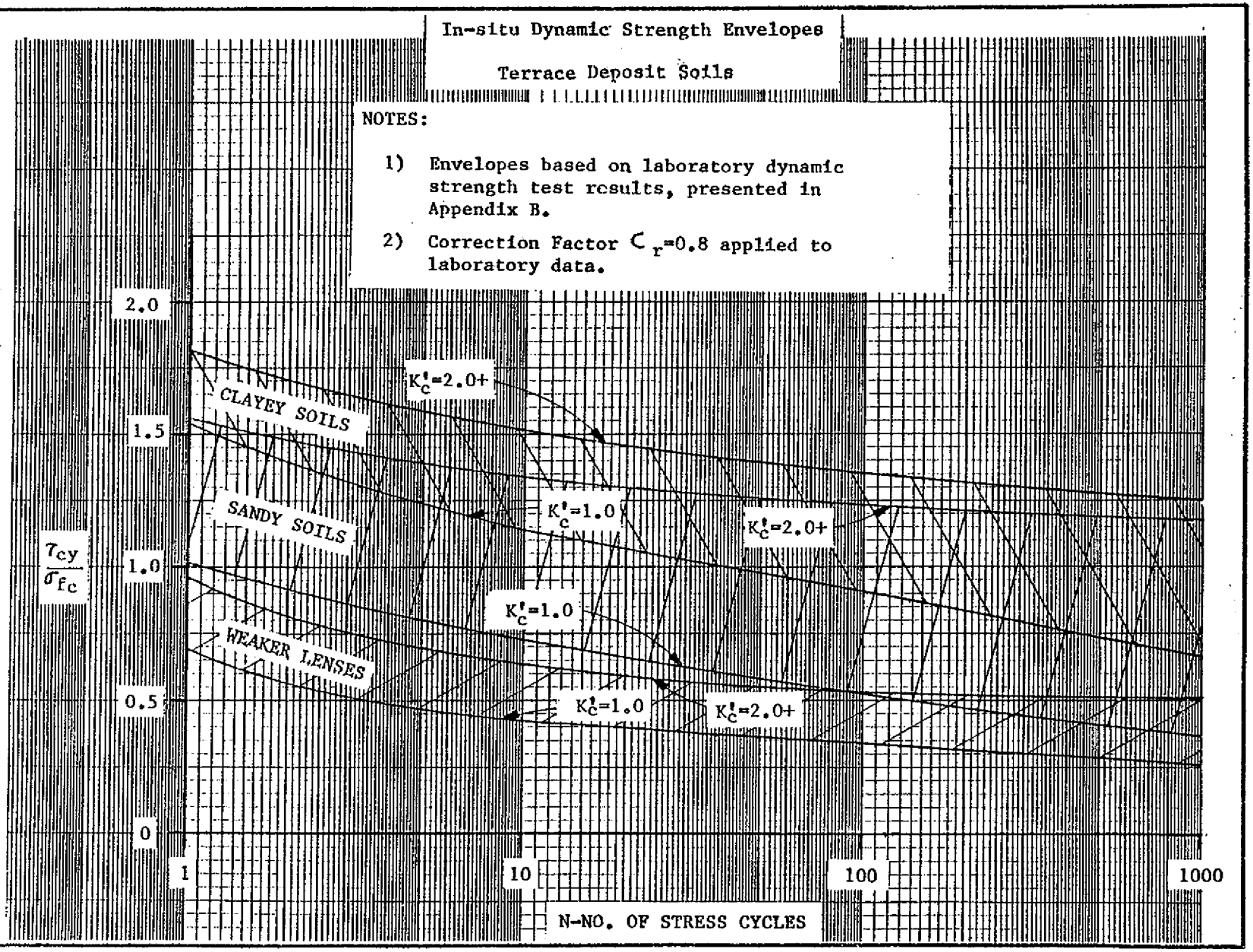


Project: SONGS SLOPE STABILITY **Job Number:** B469A4	SONGS UNITS 2 & 3 SITE 1928	Fig. 3



Project: SONGS SLOPE STABILITY **Job Number:** B469A4	SONGS UNITS 2 & 3 SITE 1972	Fig. 4



PROJECT: SONGS SLOPE STABILITY
JOB NUMBER: 3439A4

IN-SITU DYNAMIC STRENGTH ENVELOPES - TERRACE DEPOSIT SOILS

Fig. 5

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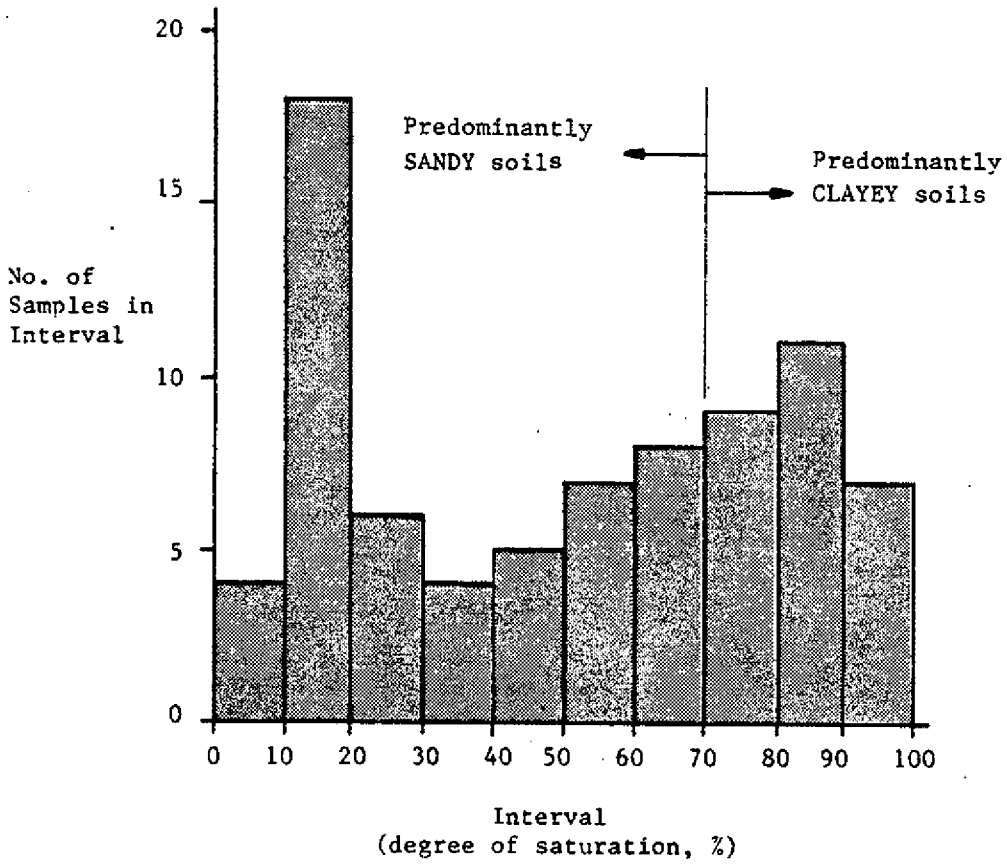
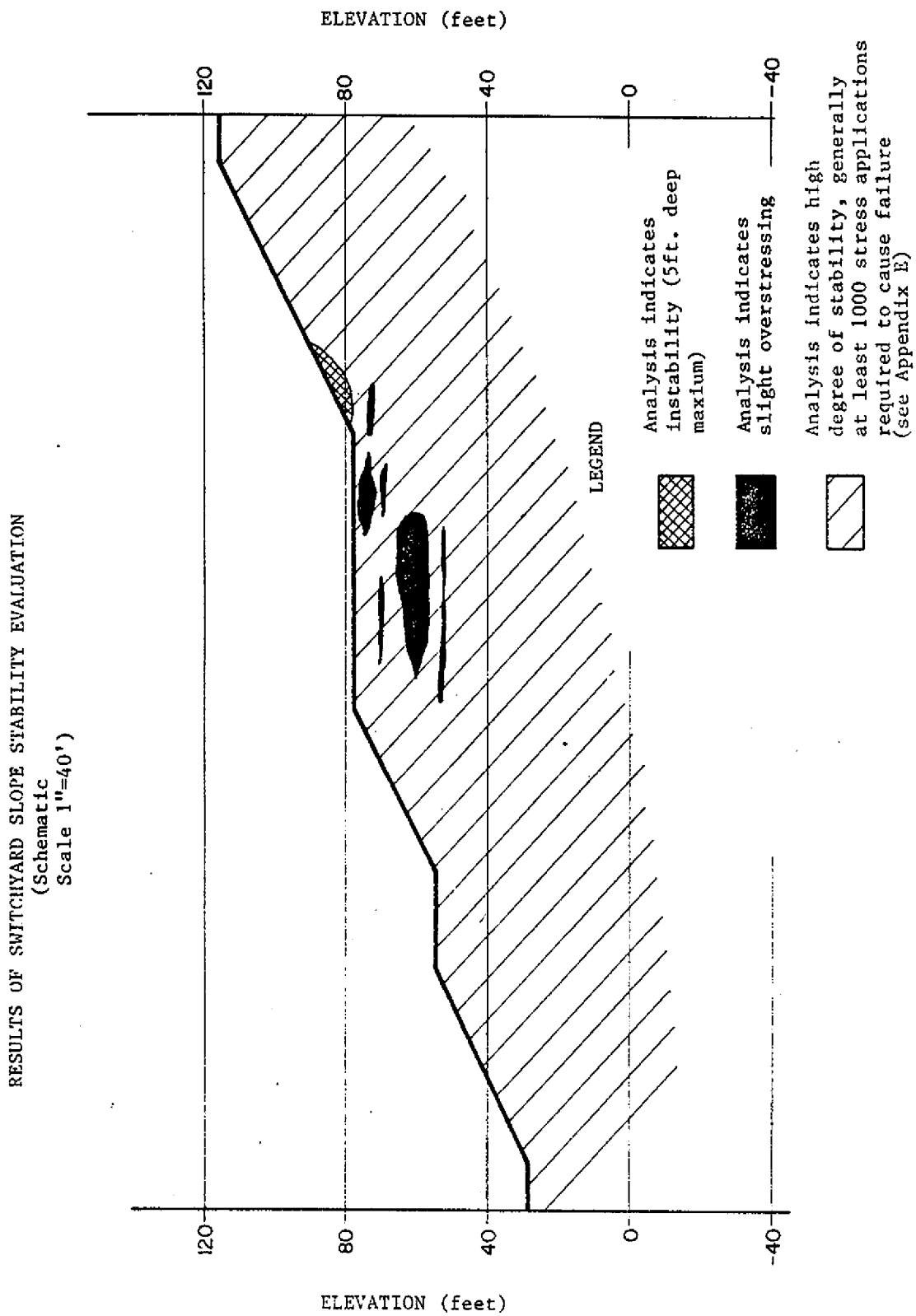


NOTES:

1) 79 samples analyzed
2) Average degree of saturation is 50%

Project: SONGS SLOPE STABILITY **Job Number**: B469A4	DISTRIBUTION OF TEST RESULTS DEGREE OF SATURATION ANALYSIS	Fig. 6

Amended: April 2009 TL: E048000



Project: SONGS SLOPE STABILITY Job Number: 3469A4	RESULTS OF STABILITY EVALUATION	Fig. 7

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Amended: April 2009 TL: E048000

Project: SONGS SLOPE STABILITY
Job Number: 346034

ZONES OF FACTOR OF SAFETY

Fig. 8

LEGEND

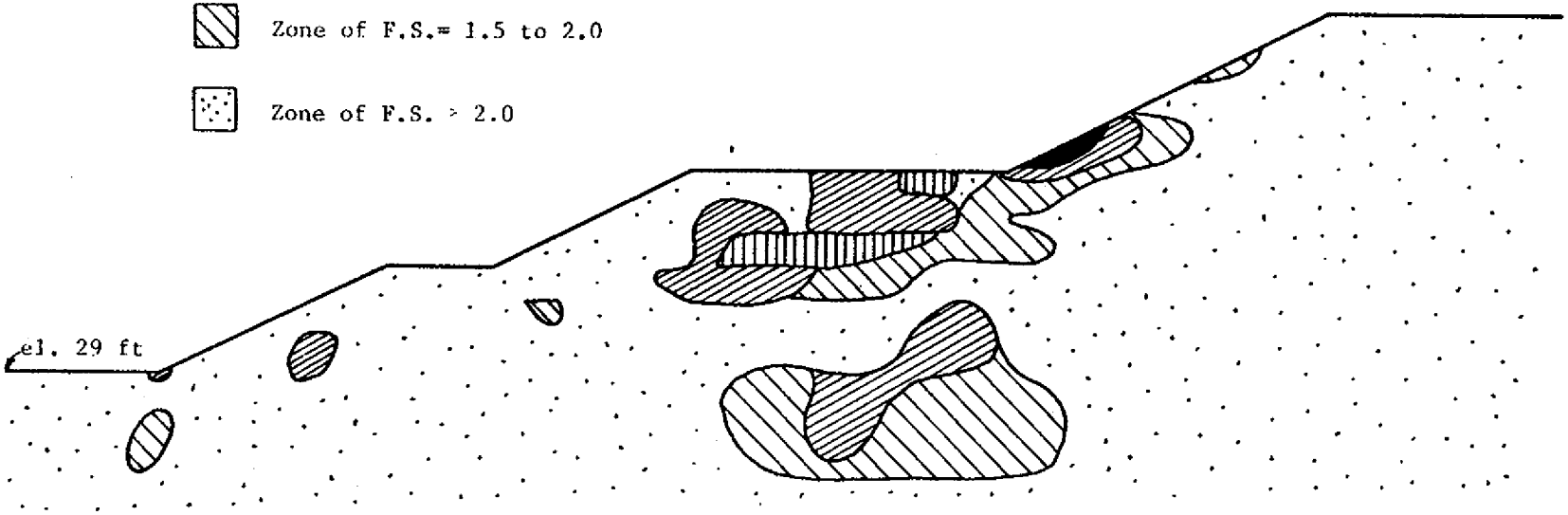
Zone of F.S.= 0.5 to 0.9 (potential instability)

Zone of F.S.= 0.8 to 1.0 (potential overstressed zone)

Zone of F.S.= 1.1 to 1.5

Zone of F.S.= 1.5 to 2.0

Zone of F.S. > 2.0



Scale 1" = 40'

(See Fig. 7 for interpreted results)

$$F.S. = \frac{\text{Dynamic Stress at 10\% strain for 80 stress applications}}{\text{65\% of Seismic Induced Stress}}$$

WOODWARD-McNEILL & ASSOCIATES

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APPENDIX A

FIELD INVESTIGATION

Between 19 Mar and 2 Apr 74, 13 borings were made at the site for this study. It was originally planned to make 5 to 10 borings of about 100 ft average depth (as described in Amendment No. 19 to the PSAR, p. 1.8 - 2bo). The intent was to have all borings penetrate into the San Mateo Formation. However, at the time of our field investigation grading was in progress, therefore it was not necessary to make borings as deep as planned in order to reach the San Mateo Formation. The locations of these borings, as well as those made during previous studies, are shown on the Site Plan, Fig. 1

Borings were advanced with a 6 in. diameter continuous flight auger drilling rig and a 5 in. diameter rotary drilling rig using mud. The rotary drilling rig was used for the purpose of advancing a Pitcher Barrel Sampler to obtain additional laboratory dynamic test specimens. It was determined during the initial phase of rotary drilling that drilling mud did not alter the moisture content of samples, therefore borings were advanced by this method rather than air-drilling techniques, as originally planned.

Samples were generally taken at 5 ft intervals with a modified California Sampler, a Pitcher Barrel Sampler, and with Shelby Tubes. In addition, bulk samples were obtained from cuttings removed from the borings. Details of the drilling and sampling program are given on the Key to Boring Logs, Fig. A-1. Boring logs, which are based on examination of

Amended: April 2009 TL: E048000

soil samples obtained during drilling, and laboratory test results, are presented on Figs. A-2 through A-14.

In addition to logging and sampling the borings, the slope face was closely examined as it was exposed during grading, and carved block samples were obtained. This procedure was used in lieu of making five test pits (as discussed in Amendment No. 19 to the PSAR, p. 1.8 - 2bo) because more detailed and representative data could be obtained.

These data, laboratory test results (Appendix B), air photos, and information generated from previous studies were used to evaluate soil properties and distribution, which are discussed in Appendix C.

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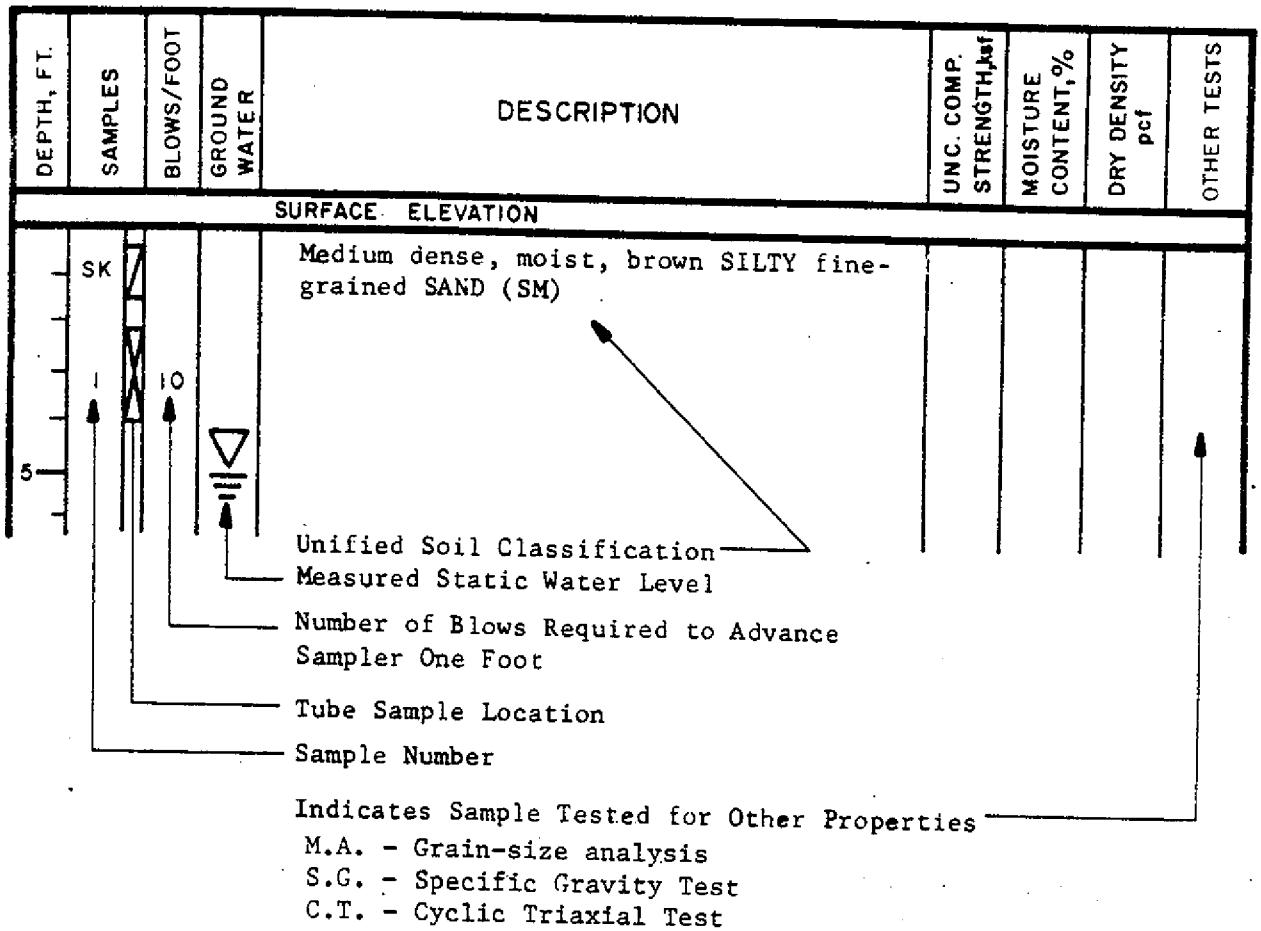

Notes on Field Investigation

1. Borings were advanced with a 6" diameter continuous flight auger or a 4 7/8" diameter rotary drilling rig using mud.
2. Samples with recorded blows/ft. (labeled M1, M2, etc.) were obtained with a Modified California drive sampler (2" inside diameter) lined with sample tubes. Samples labeled ST1, ST2, etc. were obtained with Shelby Tubes (2.78" inside diameter) hydraulically driven. Samples labeled P1, P2, etc., were obtained with a Pitcher Core Barrel Sampler.
3. Classifications are based upon the Unified Soil Classification System, and include color, moisture, and consistency. Field descriptions have been modified to reflect results of laboratory analyses where deemed appropriate.
4. NR indicates no sample recovery.

Project: SONGS SLOPE STABILITY Job Number: B469A1	KEY TO BORING LOGS	Fig. A-1

WOODWARD MITCHELL & ASSOCIATES Amended April 2008 TL: E048000

DATE OF BORING 19 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES California and Shelby Tube

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 102'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
	SK 1			Medium stiff, moist, dark brown SANDY CLAY (CL) (Fill)				
	M1	62		Very dense, moist, CLAYEY SAND (SC) with GRAVEL		12.3	119	SG
				Increasing CLAY content				
10	M2	56				7.4	121	SG MA
	M3	78				12.6	125	SG
	SK 2			Very dense, damp, brown SILTY SAND (SM) with GRAVEL				
20	M4	73				4.9	121	SG
				Dense, damp, light brown GRAVELLY SAND (SW)				
	M5	34				7.2	125	SG MA
	ST 1			Dense, moist, reddish brown SILTY SAND (SM)		17.	111	CT
30	M6	76		Dense to very dense, damp, light brown GRAVELLY SAND (SW)		2.9	105	SG
				Lens of SILTY SAND (SM)				
				With COBBLES to 6"				
	M7	40		Lens of SANDY SILT (ML)		6.4	125	SG
40	M8	40.				10.6	115	SG
	ST 2							
				Dense, damp, brown GRAVELLY SAND (SW) with COBBLES to 5" (Unable to sample due to COBBLES)				
50								
				Dense, damp, yellow SAND (SW) SAN MATEO FORMATION				
60				Bottom of boring at 57½ ft. depth (elev. 44.5ft.)				
				No water observed in boring				
70								
80								
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 3669A1

LOG OF BORING 1

Fig. A-2

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 21 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Mod. Calif. & Shelby Tube

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 112'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
	SK 1			Medium dense, moist, brown SILTY SAND (SM) (FILL)				
	SK 2			Medium stiff, moist, dark brown SANDY CLAY (CL)				
	M1	66		Grading SILTY				
				Medium dense to dense, moist, light brown SILTY SAND (SM) with some GRAVEL		11.8	114	SG
10	SK 3			Grading dark brown				
	M1	23				3.4	120	SG
	ST 1			With COBBLES				MA
	M3	44				7.4	131	SG
20	M4	61		Grading very dense		7.8 6.8	121 134	SG
	M5	93				6.9	140	SG
				Dense, moist, reddish brown SILTY SAND (SM)				
30	M6	76				3.4	109	SG
				Very dense, damp, brown GRAVELLY SAND (SW) with COBBLES to 4"				
	M7	94		Lens of SILTY SAND (SM)		2.5	113	SG
40	M8	66				4.3	127	SG
	M9	92/9"						
				Very dense, damp, tan SILTY SAND (SM)				
50	ST 2			Very dense, moist, tan GRAVELLY SAND (SW) with COBBLES				
	M 10	90/10"				3.6	110	SG
				Caving in COBBLES				MA
60				Bottom of boring at 60½ ft. depth (elev. 51.5ft.)				
				No water observed in boring				
70								
80								
90								
00								

Project : SONGS SLOPE STABILITY
Job Number : 3469A1

LOG OF BORING 2

Fig. A-3

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 22 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Mod. Calif. & Shelby Tube

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 112'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
	SK 1			Dense, moist, dark brown CLAYEY SAND (SC)				
	M1	36		Dense, moist, light brown SILTY SAND (SM)		4.3	113	SG
	SK 2			Grades to CLAYEY SAND (SC)				
10	M2	60				11.8	129	SG
	SK 3			Stiff, moist, dark brown SANDY CLAY (CL)				
	M3	46		Grading lighter brown with GRAVEL to 3/4"		8.5	132	SG
	SK 4							
20	M4	38				8.0	129	SG
	M5	55				7.6	132	SG
				Very dense, moist, brown SILTY SAND (SM) with some GRAVEL				
30	M6	74		Reddish brown		3.4	103	SG
	SK 5			Very dense, damp, gray GRAVELLY SAND (SW)				
	M7	28		Dense, moist, reddish brown CLAYEY SAND (SC) with GRAVEL to 1"	7.75	15.9	119	SG
	ST 1							
40	M8	95		Very dense, damp, gray SAND (SP)		2.5	103	SG
	M9	94 / 10"		Very dense, damp, yellow SAND (SW) SAN MATEO FORMATION		1.7	102	SG
50	M 10	100 / 3"				2.7	105	SG
				Could not sample due to cave-in of GRAVELLY material above				
60								
	SK 6							
70				Bottom of boring at 70 ft. depth (elev. 42ft.)				
				No water observed in boring				
80								
90								
100								

Project : SONGS SLOPE STABILITY
Job Number : 3469A1

LOG OF BORING 3

Fig. A-4

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 25 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Modified California

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 112'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Stiff, damp, brown SILTY CLAY (CL) with GRAVEL				
				Grading SANDY				
10	M1	25		Medium dense, damp, brown SILTY SAND (SM) with GRAVEL to ¼"		8.2	109	SG
	M2	26		Stiff, damp, brown CLAYEY SAND (SC)	5.7	14.8	120	SG
20	M3	53		Very stiff, damp, brown SANDY CLAY (CL)	14.5	13.2	124	SG
	M4	62				17.6	114	SG
30	M5	74 / 10"		Very dense, damp, gray GRAVELLY SAND (SP)		6.2	129	SG
	M6	54		Dense		4.5	108	SG
40	M7	86 / 10"		Very dense, damp, tan SILTY SAND (SM)		2.4	124	SG
	M8	96 / 10"		GRAVEL lens		2.3	118	SG
50	M9	98 / 8"				2.2	108	SG
				Bottom of boring at 51½ ft. depth (elev. 60.5ft.)				
				No water observed in boring				
60								
70								
80								
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 3469A1

LOG OF BORING 4

Fig. A-5

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 27 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Mod. Calif. & Shelby Tube

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 112'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Medium dense, damp, tan-gray GRAVELLY SAND (SW) (Fill)				
				Stiff, damp, brown SANDY CLAY (CL)				
10	ST1							
	ST2			GRAVEL lens				
	ST3			Dense, damp, brown CLAYEY SAND (SC)		7.9	111	MA CT SG
20	ST4					9.7	118	CT
				Dense, damp, brown-gray CLAYEY SAND (SC) with GRAVEL				
				GRAVEL to 2½"				
30	ST5			Dense, damp, gray-brown GRAVELLY SAND (SW)				
40	ST6							
				Dense, damp, tan SAND (SP) with GRAVEL		12	102	CT MA SG
				Grades to very dense, damp, gray-brown SILTY SAND (SM)				
50	M1	50/2"						
				COBBLES to 5"				
	M2	50/4"				3.4	121	SG
60	ST 7							
				Grading tan				
	M3	100/9"				14.5	104	SG
70	M4	50/4"				10.1	110	SG
				Very dense, damp, yellow tan SAND (SW) SAN MATEO FORMATION				
	M5	50/4"				3.3	111	SG
80				Bottom of boring at 80 ft. depth (elev. 32ft.) No water observed in boring				
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 2469A1

LOG OF BORING 4-A

Fig. A-6

WOODWARD-McNEILL & ASSOCIATES

Amended: April 2009 TL: E048000

DATE OF BORING 26 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Modified California

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION 103"

DEPTH, FT	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Medium stiff, dry, brown SILTY CLAY (CL)				
10								
				GRAVEL to 1½"				
20	M1	50/3"		Very dense, damp, tan-brown CLAYEY SAND (SC)				SG
				GRAVEL to 3"				
	M2	95/9"		Very dense, damp, tan SAND (SM-SP) with GRAVEL		4.3	125	SG
30	M3	56						SG
	M4	50/5"				4.3	120	SG
40	M5	56		Dense, damp, brown CLAYEY SAND (SC) with GRAVEL		6.4	129	SG
	M6	NR						
				Grading with less GRAVEL				
50	M7	50/4"						
	M8	50/4"		Very dense, damp, yellow SAND (SW) SAN MATEO FORMATION		2.9	118	SG
	M9	50/4"		Sample disturbed		2.1	108	SG
60	M 10	50/4"						
	M 11	50/5"				2.2	124	SG
				Bottom of boring at 56½ ft. depth (elev. 36.5ft.) No water observed in boring				
70								
80								
90								
100								

Project : SONGS SLOPE STABILITY
Job Number : 3469A1

LOG OF BORING 5

Fig. A-7

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 29 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Mod. Calif. & Shelby Tube

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 107'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Stiff, damp, brown SANDY CLAY (CL) (Fill)				
	M1	54		Dense, damp, brown CLAYEY SAND (SC)				
10	ST 1			Dense, moist, brown GRAVELLY SAND (SW)				
	M2	49		Dense, damp, brown CLAYEY SAND (SC)	12.3	11.7	134	SG
20	ST 2							
	M3	75/9"		GRAVEL to 2"		2.7	116	SG
30	ST 3							
	M4	56		Dense, damp, tan SAND (SP)		2.9	110	SG
40	ST 4			Dense, damp, brown GRAVELLY SAND (SP-SW)				
	M5	50		Dense, damp, tan SILTY fine-grained SAND (SM)				
				Dense, damp, tan GRAVELLY SAND (SW)		16.7	113	SG
50	M6	NR 50/2"						
	M7	NR		Very dense, damp, yellow SAND (SW) SAN MATEO FORMATION				
				Bottom of boring at 56 ft. depth (elev. 51ft.) No water observed in boring				
60								
70								
80								
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 3169A1

LOG OF BORING 6

Fig. A-8

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 29 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Mod. Calif. & Shelby Tube

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 116'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Stiff, damp, dark brown SANDY CLAY (CL) (Fill)				
	M1	50		Very dense, damp, brown CLAYEY fine-grained SAND (SC)		2.8	122	SG
10	ST 1							
	M2	60				9.5	127	SG
20	ST 2					11.0	122	CT MA SG
	M3	74		Hard CLAY		8.3	138	MA SC
30	ST 3							
	M4	96 / 10"		Dense, damp, gray GRAVELLY SAND (SW-SP)		2.0	114	SG
40	ST 4			GRAVEL content decreasing				
	M5	74		Very dense, dry, tan fine-grained SAND (SP)		1.4	103	SG
50	ST 5			Grading with coarse-grained SAND GRAVEL				
	M6	50 / 3"				2.4	99	SG
60	ST 6							
	M7	50 / 3"		Very dense, damp, tan SAND (SW) SAN MATEO FORMATION				
70				Bottom of boring at 66 ft. depth (elev. 50ft.). No water observed in boring				
80								
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 24931

LOG OF BORING 7

Fig. A-9

WOODWARD-McNEILL & ASSOCIATES

Amended: April 2009 TL: E048000

DATE OF BORING 25 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES 2" Modified California

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 104'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Stiff, damp, brown SANDY CLAY (CL)				
40								
	M 1	61				12.4	130	SG
20	M 2	43			7.4	15.9	119	SG
	M 3	50/5"	NR	Dense, damp, tan GRAVELLY SAND (SP-SM)				
30	M 4	42				2.0	95	MA SG
	M 5	44		CLAY lens		15.7	114	SG
40	M 6	40		Stiff, moist, brown SANDY CLAY (CL)	12.0	16.3	118	SG
	M 7	50/2"		Very dense, damp, tan SILTY SAND (SM)				
50	M 8	50/5"				4.6	113	SG
	M 9	50/2"		SAN MATEO FORMATION Very dense, damp, white SAND (SW) SAN MATEO FORMATION				
60				Bottom of boring at 56½ ft. depth (elev. 47.5ft.) No water observed in boring				
70								
80								
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 3469A1

LOG OF BORING 8

Fig. A-10

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 29 Mar.74 WATER DEPTH NONE DATE MEASURED _____ SAMPLES Pitcher Barrel

TYPE OF DRILL RIG Rotary Auger & Mud HOLE DIAMETER 6" WEIGHT OF HAMMER _____ FALLING _____

SURFACE ELEVATION: 104'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
	SK 1			Fill, COBBLES, concrete and CLAY				
	P1			Very stiff, damp, dark brown SANDY CLAY (CL) to CLAYEY SAND (SC)				
10	P2							
	P3			Brown SAND (SW)		13.8	118	CT MA SG
	P4					15.8	122	CT SG MA
	P5							
20						15.2	118	CT
	P6					8.4	127	CT SG MA
	P7							
	SK 2			Dense, damp, tan GRAVELLY SAND (SP-SW)		11.5	116	CT SG MA
30	SK 3							
				No GRAVEL				
	SK 4							
40	P8			No GRAVEL				
	P9							
	P10							
50	SK 4			Dense, damp, tan SANDY GRAVEL (GP)				
	P11			Very dense, damp, light yellow SAND (SW) SAN MATEO FORMATION				
60				Bottom of boring at 59ft. depth (elev. 45ft.) No water observed in boring				
70								
80								
90								
00								

Project: SONGS SLOPE STABILITY
Job Number: 34691L

LOG OF BORING 9

Fig. A-11

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 29 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Pitcher Barrel

TYPE OF DRILL RIG Rotary with Mud HOLE DIAMETER 6" WEIGHT OF HAMMER _____ FALLING _____

SURFACE ELEVATION: 98'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Asphalt Concrete				
				Stiff, damp, brown SILTY CLAY (CL) with GRAVEL (FILL)				
	P1			SILTY SAND (SM)				
	P2							
10	P3			Dense, moist, dark brown SANDY SILT (ML) with organic root material				
	P4			Very dense, damp, gray CLAYEY SAND (SC)				
				Grading brown				
						10.8	127	CT SG MA
	P5			Very stiff, damp, light brown SANDY CLAY (CL)		11.7	127	CT SG
20	P6					8.0	127	MA CT
	P7							MA
	SK1					20.5	127	SG CT
				Dense, damp, gray GRAVELLY SAND (SP-SW)				MA SG
	SK2							
30				No GRAVEL				
	P8			Dense, damp, brown SAND (SC) with GRAVEL and COBBLES				
	SK3							
40	P9							
	P10							
	P11			Lens of CLAY (CL)				
	SK4			Very dense, damp, brown SANDY GRAVEL (GP)				
50	P12			Very dense, damp, yellow SAND (SW) SAN MATEO FORMATION				
				Bottom of boring at 51½ ft. depth (elev. 46.5ft.)				
				No water observed in boring				
60								
70								
80								
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 3469A1

LOG OF BORING 9A

Fig. A-12

WOODWARD-McNEILL & ASSOCIATES

Amended: April 2009 TL: E048000

DATE OF BORING 28 Mar.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Pitcher Barrel

TYPE OF DRILL RIG Rotary & Mud HOLE DIAMETER 6" WEIGHT OF HAMMER _____ FALLING _____

SURFACE ELEVATION: 94'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Very dense, damp, dark brown, SILTY SAND (SM)				
10	P1					12.1	118	CT MA SG
	P2							
	P3					14.4	121	CT MA SG
	P4							
20	SK 1			Very dense, damp, brown GRAVELLY SAND (SP-SW)				
30				COBBLES to 4"				
				Refusal on COBBLES				
40				Bottom of boring at 38 ft. depth (elev. 56ft.)				
				No water observed in boring				
50								
60								
70								
80								
90								
100								

Project: SONGS SLOPE STABILITY

Job Number: 3469A1

LOG OF BORING 10

Fig. A-13

WOODWARD-McNEILL & ASSOCIATES

DATE OF BORING 2 Apr.74 WATER DEPTH _____ DATE MEASURED _____ SAMPLES Mod. Calif. & Shelby Tube

TYPE OF DRILL RIG Cont. Flight Auger HOLE DIAMETER 6" WEIGHT OF HAMMER 140 lbs. FALLING 30"

SURFACE ELEVATION: 94'

DEPTH, FT.	SAMPLES	BLOWS / FOOT	GROUND WATER	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
				Medium dense, moist, dark brown SILTY SAND (SM)				
				Dense				
	M1	39			2.8			MA
10	ST 1			Hard, damp, brown SANDY CLAY (CL)		13.3	119	CT MA SG
	M2	56		Dense, damp, tan SILTY SAND (SM-SP)		4.0	112	SG MA
20	ST 2	NR		With GRAVEL				
	M3	50				1.9	111	SG
	M4	44				2.8	120	SG
30	M5	50/5"		Grading very dense		3.5	124	SG MA
				Grading with COBBLES, caving				
				Bottom of boring at 35 ft. depth (elev. 59ft.)				
				No water observed in boring				
40								
50								
60								
70								
80								
90								
100								

Project: SONGS SLOPE STABILITY
Job Number: 3469A1

LOG OF BORING 10A

Fig. A-14

WOODWARD-McNEILL & ASSOCIATES

APPENDIX B

LABORATORY INVESTIGATION

B-1 Index Tests

Laboratory tests were performed on selected samples in order to determine pertinent soil properties. Density, moisture content, and specific gravity determinations were made for all drive tube and pitcher samples obtained from the borings. Also, unconfined compression tests were performed on a number of specimens. The results of moisture, density, and unconfined compression (static strength) tests are presented on the Logs of Borings (Appendix A) for ease in correlation with the soil profile. The results of specific gravity tests are summarized on Table B-1. The results of grain-size distribution tests are presented on Figs. B-1 through B-9.

B-2 Cyclic Triaxial Tests

Dynamic testing was performed on pitcher, shelby tube, and carved block samples by stress-controlled cyclic triaxial techniques. Of the two carved block samples obtained, one was not thought homogeneous enough for meaningful dynamic testing. The carved block sample test results were not compared with the corresponding Pitcher Sample test results to evaluate possible effects of disturbance during sampling, as originally planned, because slight differences in sample composition made correlation difficult. Therefore, for conservatism, no strength increase was applied to drive tube sample test results in this evaluation. A total of 28 specimens were tested. A summary of test data is presented on Table B-2.

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Each test specimen was trimmed, placed between platens, encased in a rubber membrane, then subjected to an initial triaxial confining pressure of the same magnitude as the original field overburden pressure of the sample (column 4 of Table B-2) and allowed to stabilize prior to testing. The test was performed by cycling a pre-determined increment of deviator stress (at 1 hertz), consistent with post-construction stress conditions, and measuring induced strain and porewater pressure. Samples were tested at field moisture content.*

Principal strain of 10% (or ±5% strain) was considered failure. For tests in which the strain did not reach 10% within a few hundred cycles, the tests were stopped and restarted with a higher deviator stress. The dynamic test results are plotted on Figs. B-10 and B-11 for isotropic and anisotropic tests, respectively. Interpreted laboratory strength envelopes are also shown on those figures.

The dynamic tests were also used to estimate modulus and damping characteristics of the terrace soils. For a number of samples, calculations were made of Young's Modulus and hysteretic damping for the fifth stress cycle of each test. The calculated values, presented on Table B-2, columns 13, 14, and 15, correlated well with assumed modulus and damping values assumed for the previous analysis. However, tests indicate the terrace deposit sands are stiffer than previously

*with the exception of test no. 85, for which the specimen was inadvertently saturated for 12 hrs.

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assumed. Therefore modulus values were adjusted accordingly for the present analysis.

In addition, one large-diameter (4-in.) stress-controlled dynamic test, with 1/3-point and diametral strain measurements, was performed on a sample of the carved block material. This test indicated that the Poisson's Ratio assumed during the previous study was appropriate, and that end effects were negligible (i.e., no correction to platen-to-platen strain measurements were required).

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TABLE B-1

RESULTS OF SPECIFIC GRAVITY TESTS

Boring No.	Sample No.	Specific Gravity
1	M-1	2.80
	M-2	2.76
	M-3	2.76
	M-4	2.69
	M-5	2.73
	M-6	2.69
	M-7	2.72
	M-8	2.77
2	M-1	2.72
	M-2	2.77
	M-3	2.80
	M-4	2.76
	M-5	2.77
	M-6	2.68
	M-7	2.67
	M-8	2.74
	M-10	2.67
3	M-1	2.51
	M-2	2.77
	M-3	2.76
	M-4	2.73
	M-5	2.70
	M-6	3.10
	M-7	2.77
	M-8	2.64
	M-9	2.67
	M-10	2.64
4	M-1	2.68
	M-2	2.76
	M-3	2.75
	M-4	2.79
	M-5	2.72
	M-6	2.65
	M-7	2.73
	M-8	2.63
	M-9	2.65
4A	ST-6	2.67
	M-2	2.68
	M-3	2.75
	M-4	2.75
	M-5	2.69
5	M-1	2.70
	M-2	2.69
	M-3	2.68
	M-4	2.73
	M-5	2.70
	M-8	2.66
	M-9	2.64
	M-11	2.65
6	M-2	2.75
	M-3	2.72
	M-4	2.70
	M-5	2.73
7	M-1	2.73
	M-2	2.75
	ST-2	2.75
	M-3	2.77
	M-4	2.65
	M-5	2.72
	M-6	2.67
8	M-1	2.73
	M-2	2.79
	M-4	2.69
	M-5	2.78
	M-6	2.81
	M-8	2.68
9	P-2	2.76, 2.72
	P-5	2.74, 2.74, 2.73
	P-7	2.75, 2.76
9A	P-4	2.74
	P-5	2.74
	P-6	2.70, 2.75
	P-7	2.72
10	P-1	2.75, 2.77
	P-2	2.75, 2.77, 2.77
10A	ST-1	2.72
	M-2	2.73
	M-3	2.68
	M-4	2.71
	M-5	2.71

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TABLE B-2

SUMMARY OF CYCLIC TRIAXIAL TEST DATA

① Test No.	② Sample No.	③ K_c'	④ σ_{3c}' (psf) pre-test	⑤ σ_3' (psf) test	⑥ Unified Soil Classification	⑦ Dry Density (pcf)	⑧ D_{50} (mm)	⑨ % Passing #200	⑩ τ_{cd} (psf)	⑪ N Stress Cycles	⑫ ε(%) Axial Strain @ N Cycles	⑬ E Calculated Modulus (ksf)	⑭ γ Hysteretic Damping (%)	⑮ ε (%) Strain for Calculations of ⑬ and ⑭
81	4A-ST3 Bottom	1.0	2300	1300	SM	111	0.5	27	1200	250	1.0	1200	24	1.0
82	1-ST1 Bottom	1.0	3400	2500	SM	113	na	na	2100	100	0.5	750	18	0.5
85*	4A-4 Bottom	1.0	2900	2800	SC	118	na	na	2300	25	10.0	na	na	na
97	4A-ST4 Middle	1.0	2900	2800	SC	109	0.14	43	2750	16	10.0	na	na	na
98	4A-ST6 Bottom	1.0	5400	5000	SP	102	0.5	3	4000	60	10.0	750	21	0.5
99	9-P2 Middle	1.0	1400	1000	SM	118	0.3	34	900	150	0.61	560	29	0.3
99A	9-P2 Middle	1.0	1400	1000	SM	118	0.3	34	990	150	0.73	na	na	na
99B	9-P2 Middle	1.0	1400	1000	SM	118	0.3	34	1460	31	10.0	na	na	na
100	9-P2 Top	1.0	1400	1000	SM	118	0.3	33	1650	31	10.0	76	25	0.4
101	10-P1 Bottom	1.0	1300	500	SM	118	0.3	45	500	150	0.2	1162	17	0.5
101A	10-P1 Bottom	1.0	1300	500	SM	118	0.3	45	800	67	0.5	na	na	na
101B	10-P1 Bottom	1.0	1300	500	SM	118	0.3	45	1150	150	6.4	na	na	na
102	10-P1 Middle	1.0	1300	1000	SM	110	0.2	38	1000	150	0.9	206	14	1.0
103	10-P2 Bottom	1.0	1300	1000	SM	121	0.1	47	1700	75	10.0	na	na	na
104	10-P2 Middle	1.0	1600	1000	SM	120	0.1	45	1850	13	10.0	192	23	3.4
105	10-P2 Top	1.0	1600	1000	SM	119	0.1	46	1750	11	10.0	220	19	1.6
106	7-ST2 Bottom	1.0	2600	1000	SC	122	0.25	35	980	150	0.12	300	26	1.0
106A	7-ST2 Bottom	1.0	2600	1000	SC	122	0.25	35	1850	475	9.0	na	na	na
107	9-P4 Bottom	1.0	2000	1500	CL	118	na	na	1380	150	0.24	1250	16	0.4
107A	9-P4 Bottom	1.0	2000	1500	CL	118	na	na	2500	150	0.74	na	na	na
107B	9-P4 Bottom	1.0	2000	1500	CL	118	na	na	3380	152	10.0	na	na	na
108	9-P4 Top	1.0	2000	1500	CL	117	na	na	3700	229	10.0	600	19	1.0
109	9-P4 Middle	1.0	2000	1500	CL	122	na	na	4000	20	10.0	245	23	3.6
110	9-P5 Bottom	1.0	2500	2500	SC	122	0.1	45	2200	156	2.5	416	10	0.1
110A	9-P5 Bottom	1.0	2500	2500	SC	122	0.1	45	4250	1	10.0	na	na	na
111	9-P5 Middle	1.0	2500	2500	SC	127	0.1	48	2500	150	0.4	120	32	0.4
112	9-P5 Top	1.0	2500	2500	SC	127	0.3	34	3380	2	10.0	na	na	na
113	9-P7 Bottom	2.0	3300	2000/1000	SW	116	0.1	47	1900	150	0.5	1100	22	0.35
113A	9-P7 Bottom	2.0	3300	2000/1000	SW	116	0.1	47	2900	167	1.3	na	na	na
113B	9-P7 Bottom	2.0	3300	2000/1000	SW	116	0.1	47	3900	1	10.0	na	na	na
114	9-P7 Middle	2.0	3300	2000/1000	CL	117	.015	66	3000	150	2.0	na	na	na
114A	9-P7 Middle	2.0	3300	2000/1000	CL	117	.015	66	3500	50	10.0	na	na	na
115	10A-ST1 Bottom	2.0	1500	3000/1500	CL	119	.02	62	2200	150	0.26	na	na	na
115A	10A-ST1 Bottom	2.0	1500	3000/1500	CL	119	.02	62	2850	150	0.31	na	na	na
115B	10A-ST1 Bottom	2.0	1500	3000/1500	CL	119	.02	62	3500	150	0.6	na	na	na
115C	10A-ST1 Bottom	2.0	1500	3000/1500	CL	119	.02	62	4500	150	1.0	na	na	na
116	9A-P5 Bottom	2.0	2000	4000/2000	SC	127	0.1	45	3850	1000	0.9	na	na	na
116A	9A-P5 Bottom	2.0	2000	4000/2000	SC	127	0.1	45	4650	1000	1.5	na	na	na
117	9A-P6 Bottom	2.5	2600	1250/ 500	CL	127	.008	76	4900	1000	7.5	na	na	na
117A	9A-P6 Bottom	2.5	2600	1250/ 500	CL	127	.008	76	5900	200	10.0	na	na	na
118	9A-P7 Bottom	2.5	3000	3250/1500	CL	97	.05	55	6850	1	10.0	na	na	na
119	9A-P4 Middle	3.0	1600	1500/ 600	SC	127	0.06	54	1800	1000	0.4	na	na	na
119A	9A-P4 Middle	3.0	1600	1500/ 600	SC	127	0.06	54	2420	1000	1.75	na	na	na

*Inadvertently saturated for 12 hours.
Test numbers followed by A, B, or C are retests.
Test numbers not in sequence as other testing program in progress concurrently.
na means not analyzed, or not tested.

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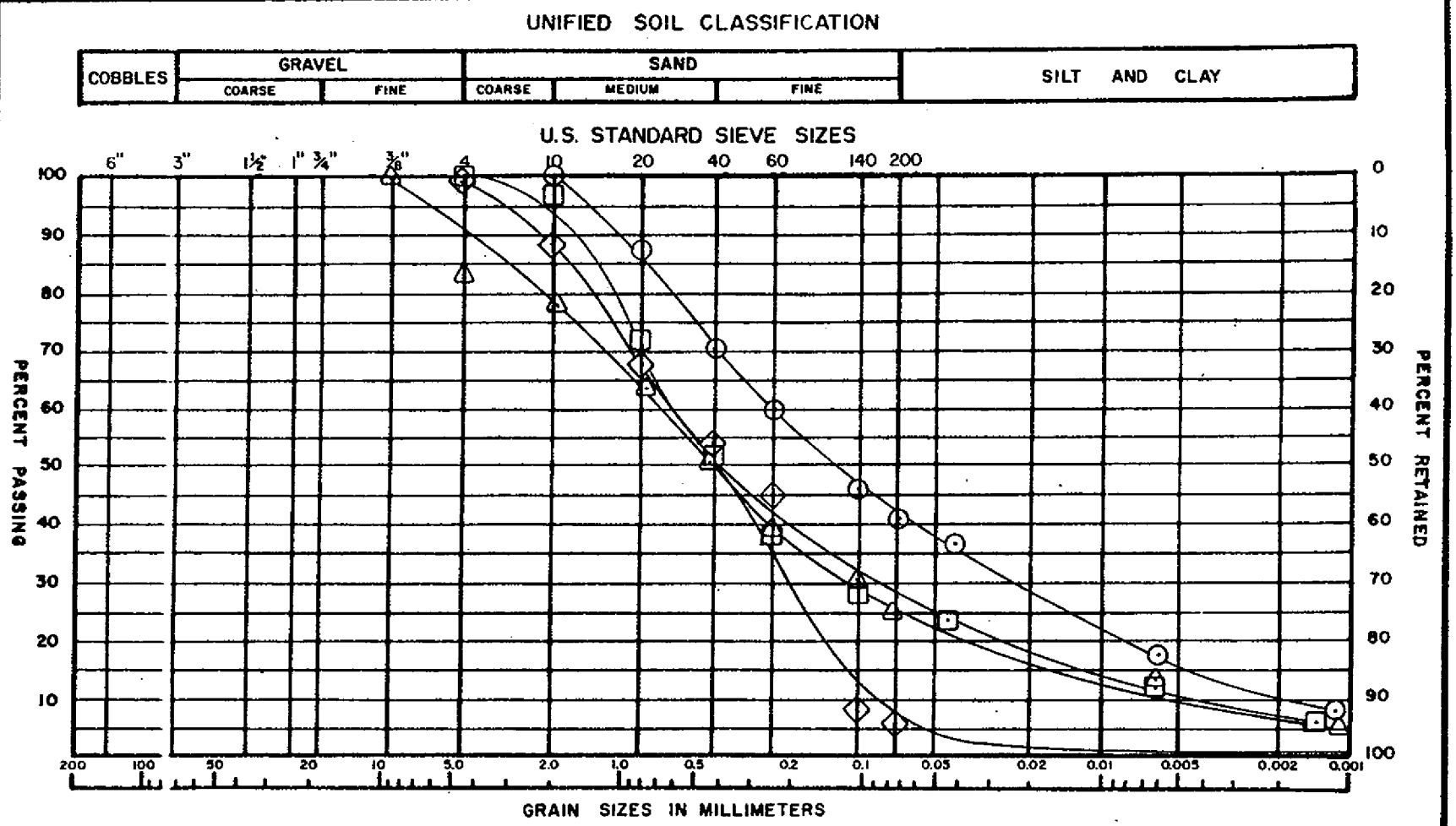
GRAIN SIZE DISTRIBUTION CURVES

Fig 3-1



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
1 – M2	11ft.	⊙——⊙			CLAYEY SAND (SC)
1 – M5	26ft.	△——△			SILTY SAND (SM)
2 – M3	11ft.	⊡——⊡			SILTY SAND (SM)
2 – M10	53ft.	◇——◇			WELL GRADED SAND (SW)

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2.5E-B7

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GRAIN SIZE DISTRIBUTION CURVES

Fig: B-2

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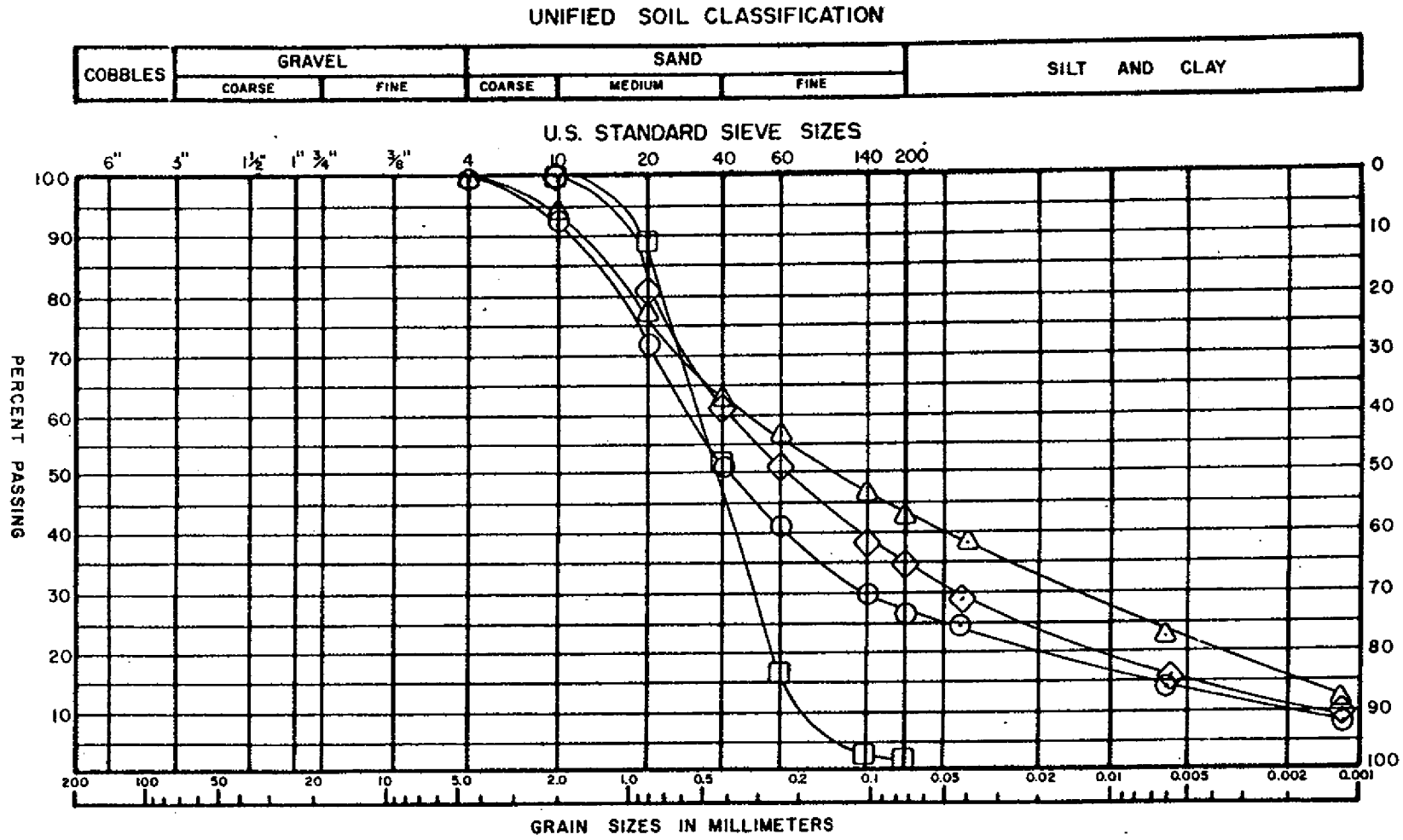

BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
4A-ST3 Bottom	18ft.	⊙——⊙			CLAYEY SAND (SC)
4A-ST4 Middle	32ft.	△——△			CLAYEY SAND (SC)
4A-ST6 Bottom	43ft.	⊡——⊡			SAND (SP)
7 -ST2 Bottom	21ft.	◇——◇			CLAYEY SAND (SC)

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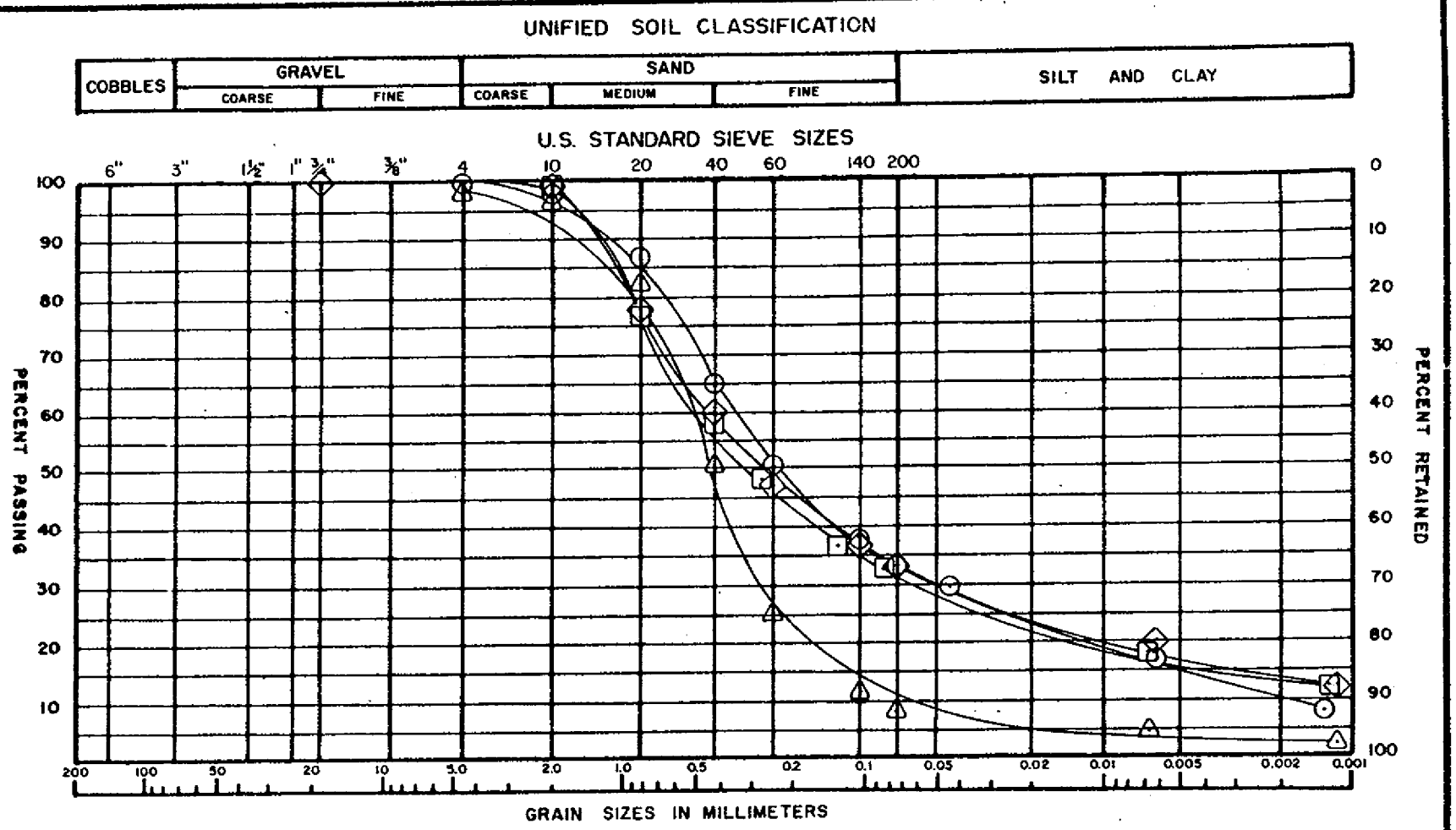
Project: SONGS SLOPE STABILITY

Job Number: P469A2

GRAIN SIZE DISTRIBUTION CURVES



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
7-M3	26ft.	⊙——⊙			SILTY SAND (SM)
8-M4	31ft.	△——△			SAND (SM-SP)
9-P2 (Middle)	11ft.	◇——◇			SILTY SAND (SM)
9-P2 (Top)	11ft.	⊡——⊡			SILTY SAND (SM)

Fig B-3

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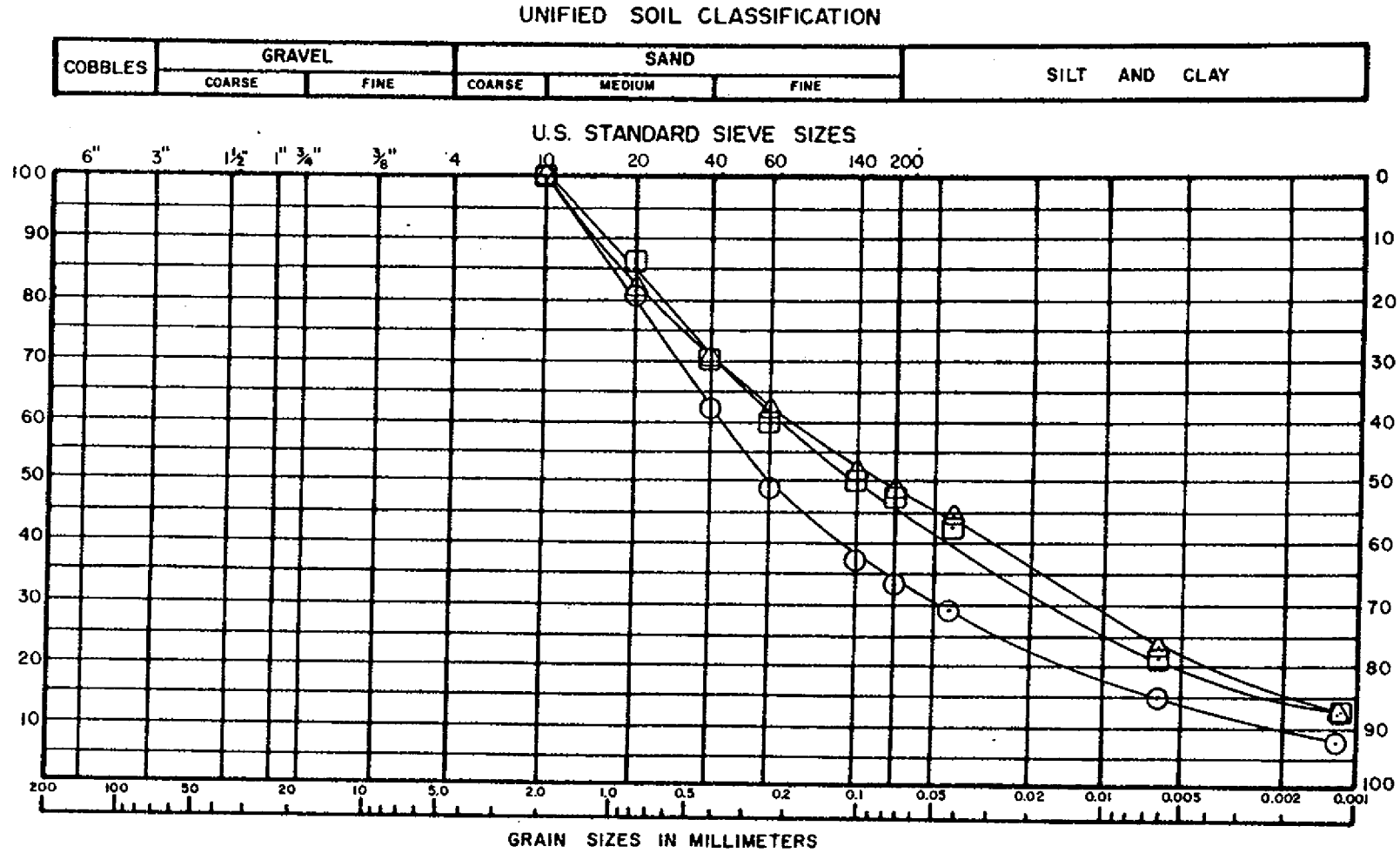
GRAIN SIZE DISTRIBUTION CURVES

Fig: B-4



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
9-5 (Top)	19'	⊙——⊙			CLAYEY SAND (SC)
9-5 (Middle)	19½'	⊡——⊡			CLAYEY SAND (SC)
9-5 (Bottom)	20'	△——△			CLAYEY SAND (SC)

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2.5E-B10

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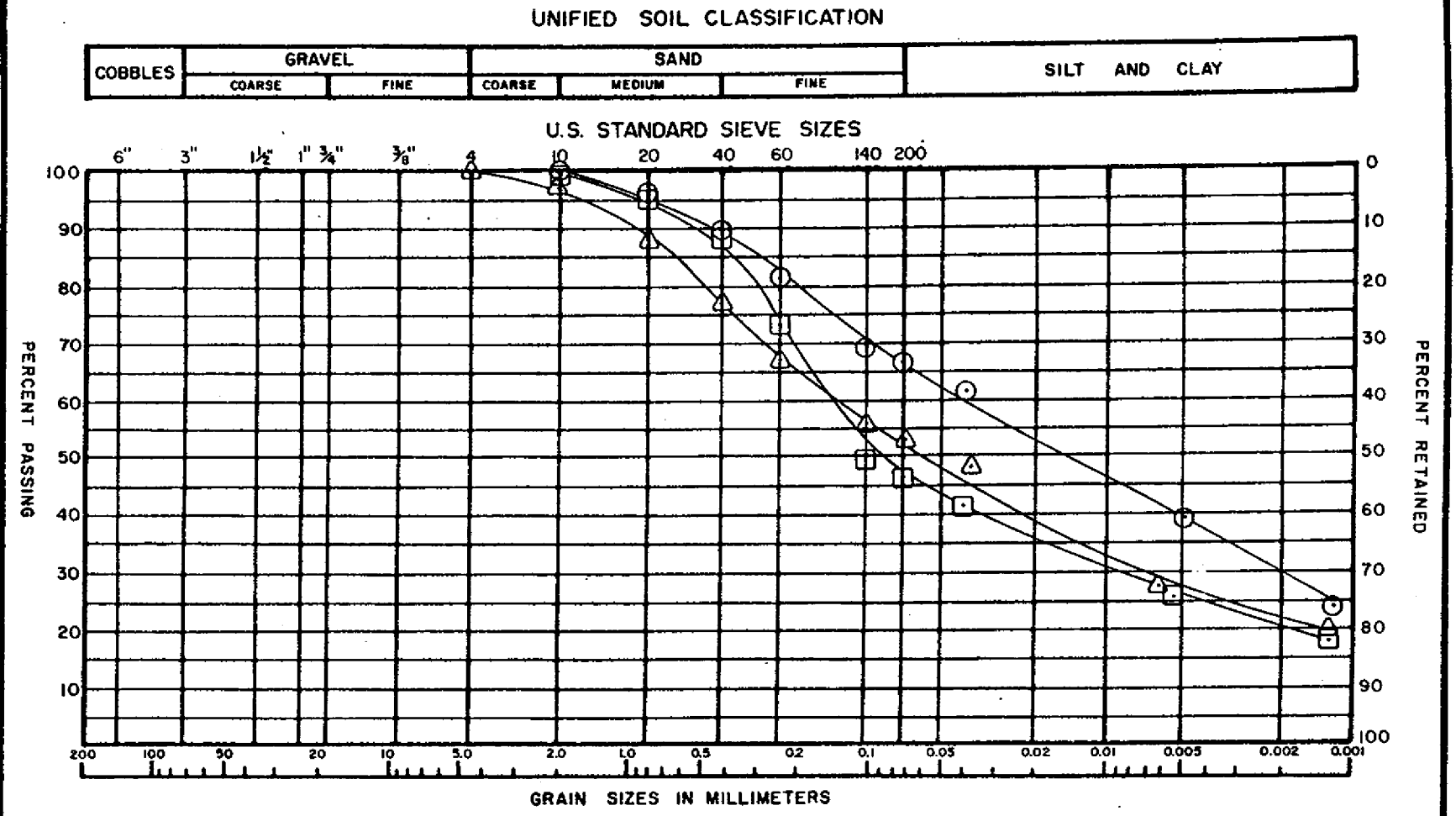
GRAIN SIZE DISTRIBUTION CURVES

Fig: B-5



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
9 - 7 (Middle)	26'	⊙——⊙			SILTY SAND (CL)
9 - 7 (Bottom)	26½'	⊡——⊡			CLAYEY SAND (SC)
9A- 4 (Middle)	14'	△——△			SANDY CLAY (CL)

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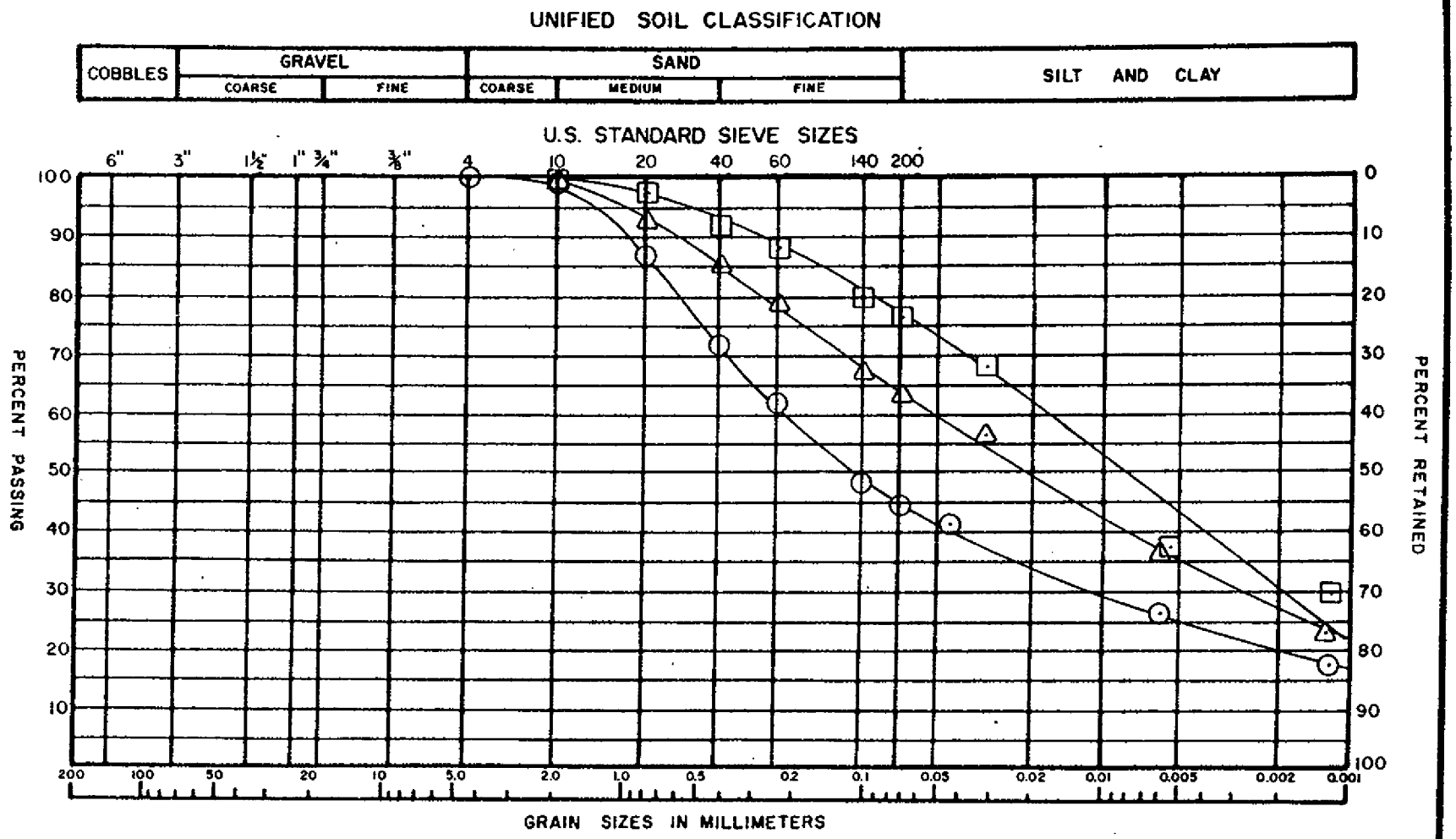
GRAIN SIZE DISTRIBUTION CURVES

Fig: 3-6



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
9A-5 (Bottom)	17½'	⊙——⊙			CLAYEY SAND (SC)
9A-6 (Middle)	20'	△——△			SANDY CLAY (CL)
9A-6 (Bottom)	20½'	⊡——⊡			SANDY CLAY (CL)

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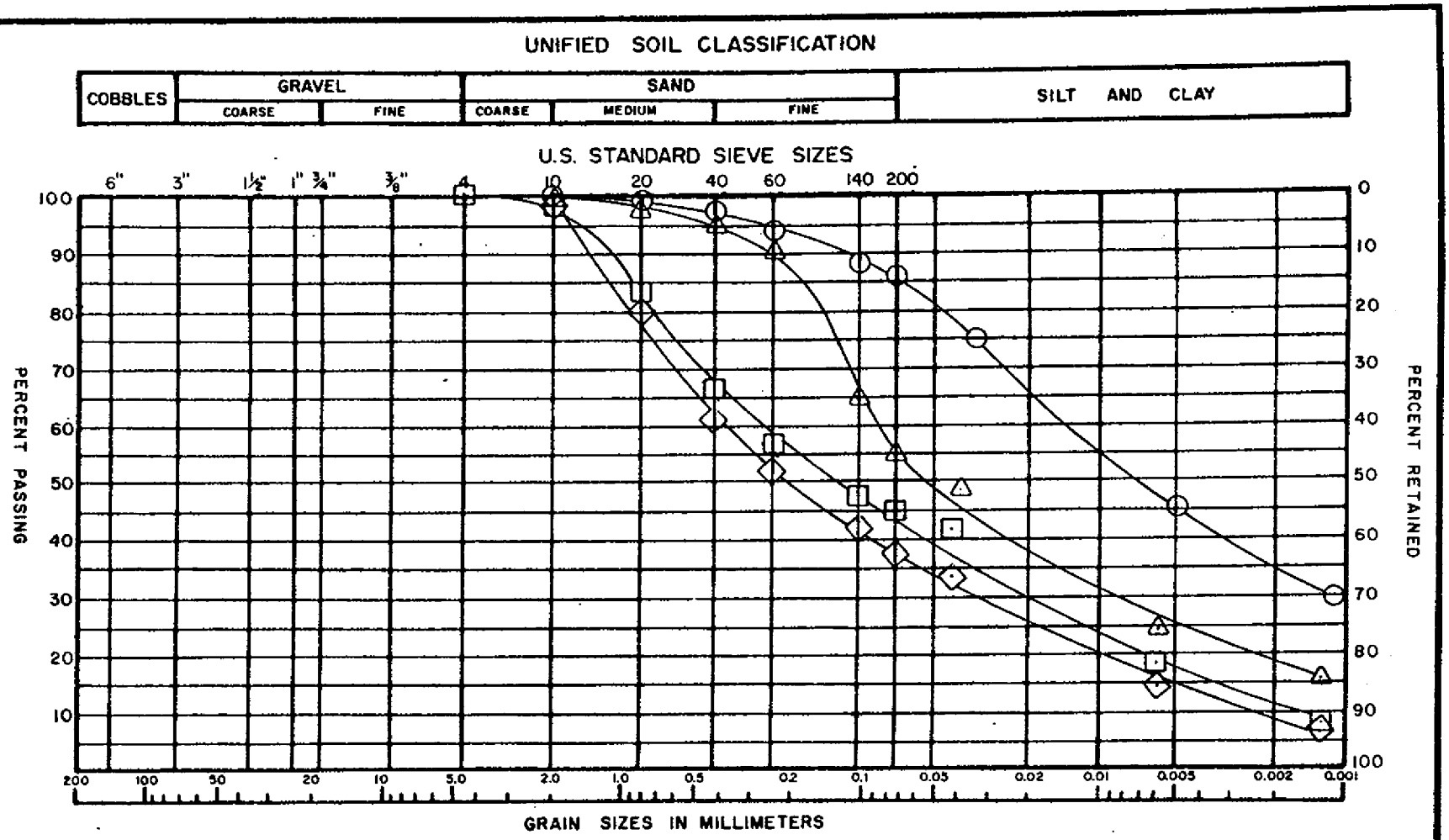
GRAIN SIZE DISTRIBUTION CURVES

Fig: B-7



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
9A-7 (Top)	22'	⊙——⊙			SILTY CLAY (CL)
9A-7 (Bottom)	23½'	△——△			SANDY CLAY (CL)
10-1 (Middle)	10'	◇——◇			SILTY SAND (SM)
10-1 (Bottom)	10½'	⊡——⊡			SILTY SAND (SM)

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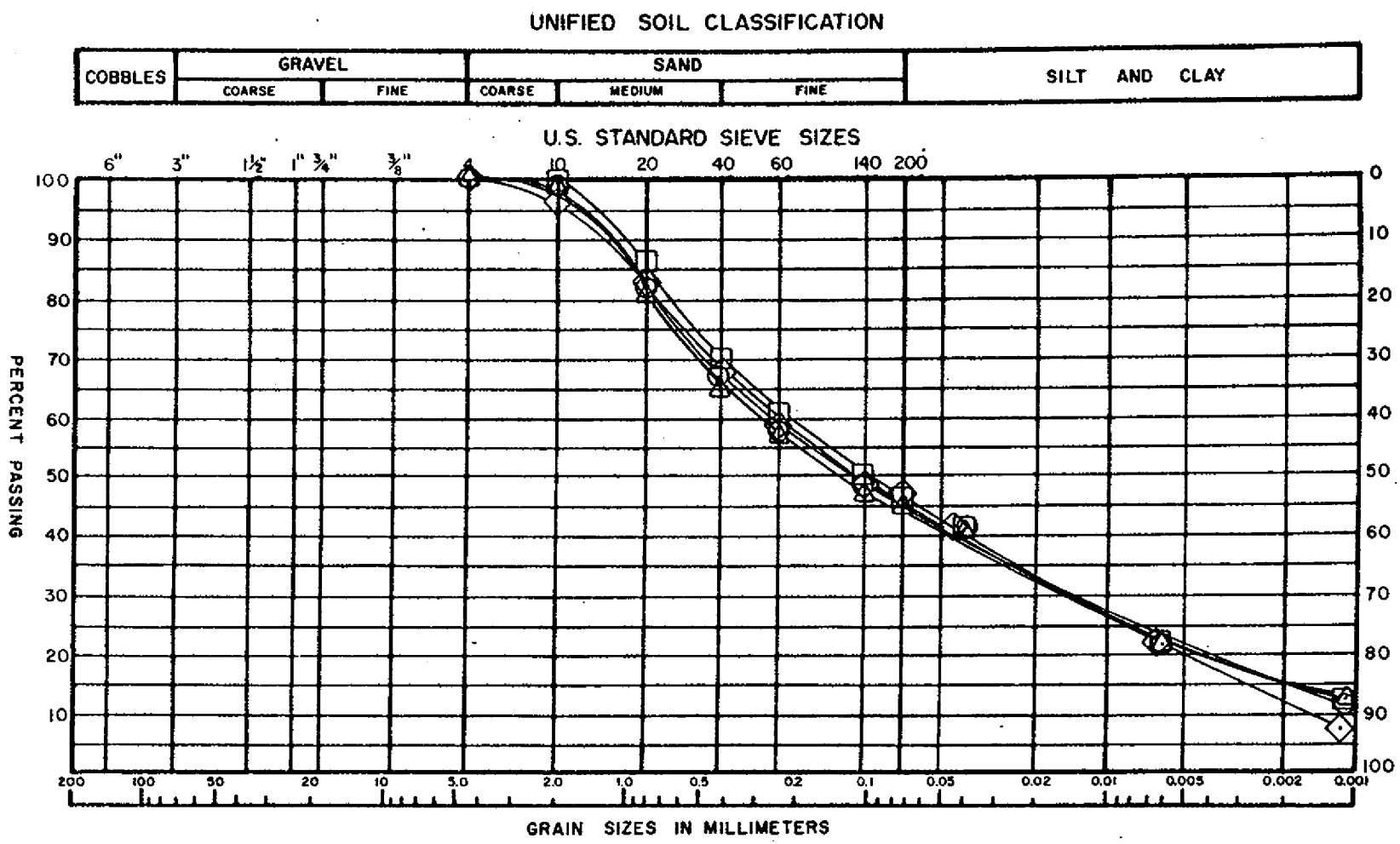
Job Number: B469A2

GRAIN SIZE DISTRIBUTION CURVES

Fig: 3-8



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
10-2 (Top)	12'	⊙——⊙			SILTY SAND (SM)
10-2 (Middle)	12½'	△——△			SILTY SAND (SM)
10-2 (Bottom)	13'	⊡——⊡			SILTY SAND (SM)
Carved Block		◇——◇			SILTY SAND (SM)

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GRAIN SIZE DISTRIBUTION CURVES

Fig: B-9

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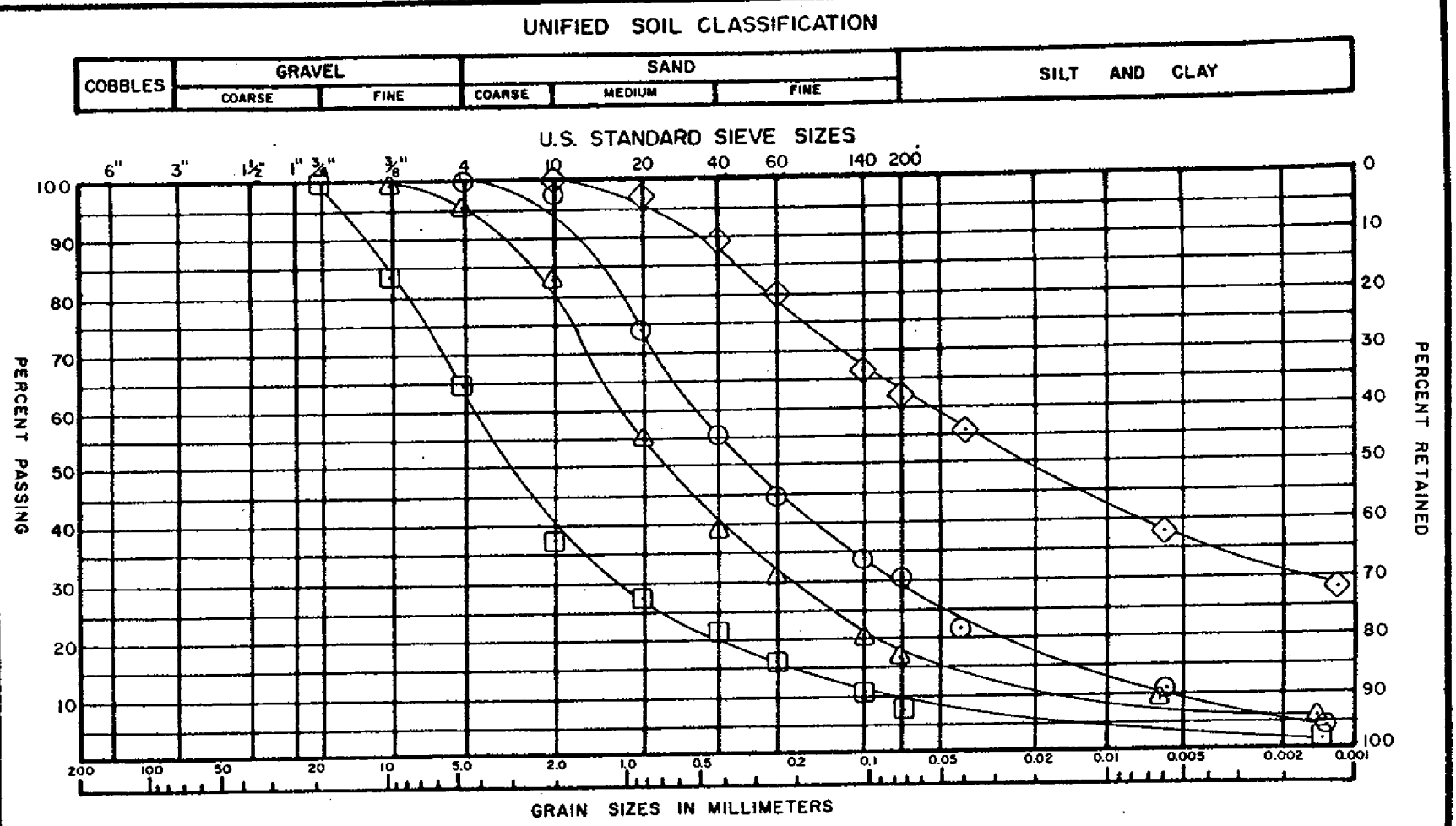

BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
10A - M1	6'	⊙——⊙			SILTY SAND (SM)
10A - M2	16'	△——△			SILTY SAND (SM)
10A - M5	30'	⊡——⊡			GRAVELLY SAND(SM-SP)
10A - ST1	11'	◇——◇			SANDY CLAY (CL)

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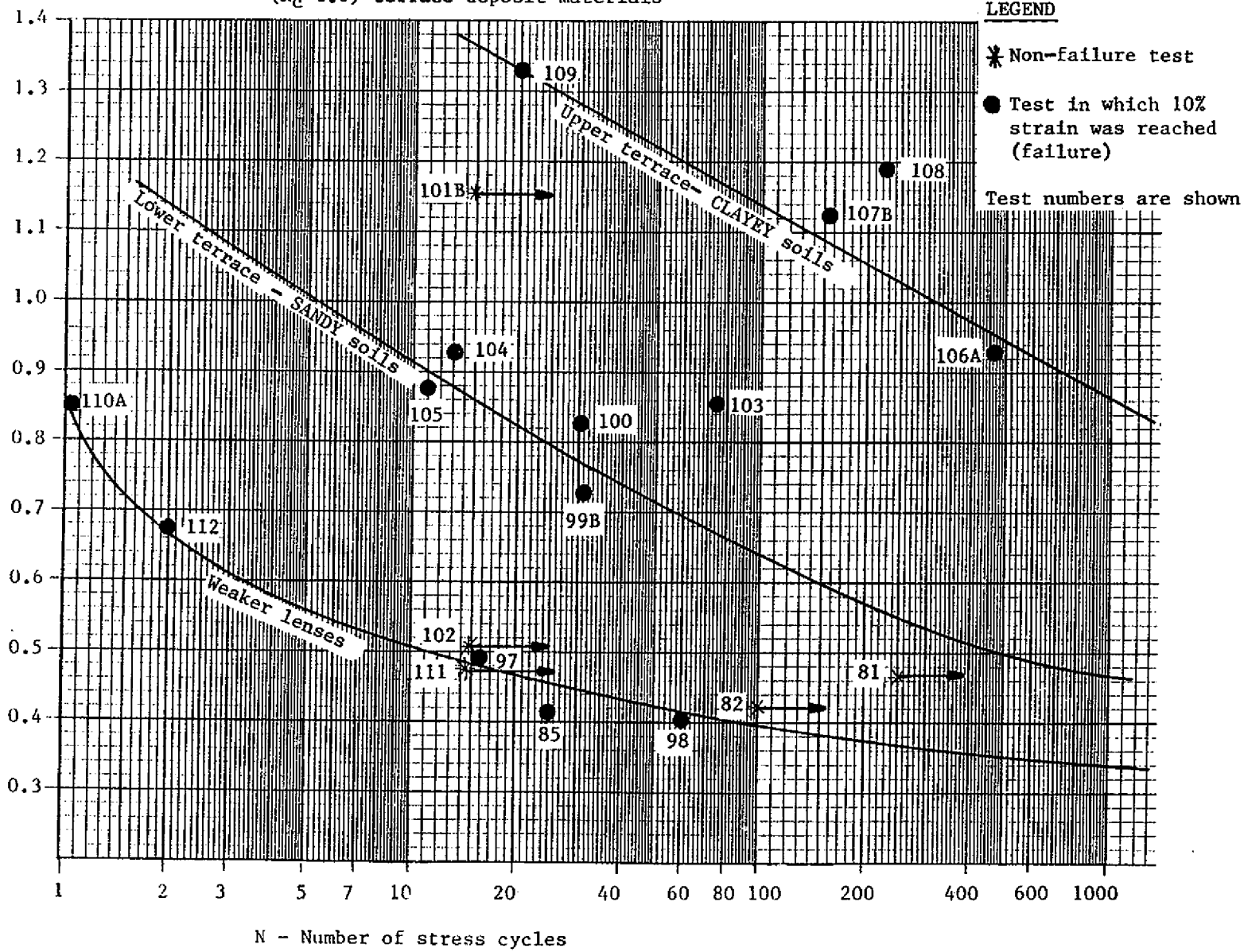
Laboratory dynamic test results Isotropic Tests
(K_c'=1.0) terrace deposit materials



Project: SONGS SLOPE STABILITY
Job Number: 346934

LABORATORY DYNAMIC TEST RESULTS
ISOTROPIC TESTS

Fig. B-10

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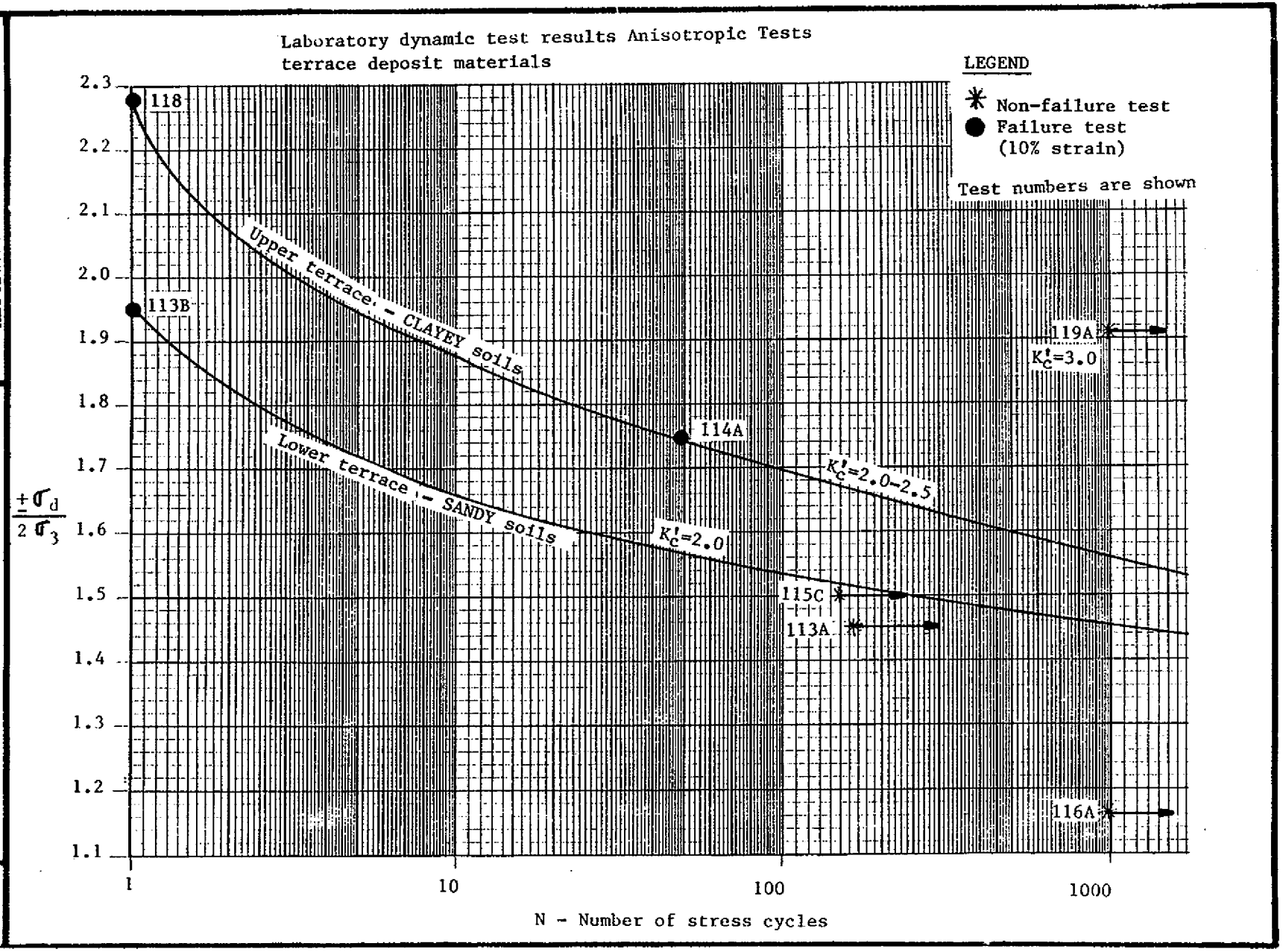

Project: SONGS SLOPE STABILITY
Job Number: B469A4

LABORATORY DYNAMIC TEST RESULTS
ANISOTROPIC TESTS

Fig. B-11

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2.5E-B17/2.5E-B18

APPENDIX C

SOIL PROPERTIES

C-1 Generalized Soil Profile

Laboratory test results, boring log data, examination of graded slopes, and data from previous studies were analyzed in order to determine a generalized soil profile for use in finite-element analyses. These data indicate the terrace deposit, which constitutes the upper portion of the switch-yard slopes, consists of interbedded, horizontally stratified, dense to very dense sandy soils and stiff clayey soils, with occassional lenses of gravel, silt, and cobbles. The clayey, more fine-grained materials appear to be predominant in the upper portions of the terrace (from approximately elevation 80 to 117 ft). The sandy, more coarse grain materials, which are interbedded with the lenses of gravel, silt, clay, and cobbles, generally lie between elevation 50 and 80 ft. This material is underlain by the San Mateo Formation Sand.

C-2 Determination of Groundwater Conditions

To aid in the determination of groundwater conditions at the site, calculations were made of the degree of saturation of 79 samples obtained from the borings. A summary plot of these test results is presented on Fig. C-1. These data indicate that 1) no samples tested were 100% saturated, 2) samples with a degree of saturation greater than 70% were predominantly clayey, and 3) the average degree of saturation

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is approximately 50%. This information, consideration of local groundwater hydrology and the fact that no free water was observed in any borings (above approximately elevation 5 ft), indicates that the terrace deposit soils are partially saturated, and that they will likely remain so assuming careful surface drainage control is implemented.

C-3 Dynamic Strength Determination

The laboratory strength tests reported in Appendix B provided the basis for estimating the in-situ strengths of the site soils. Figs. C-2 through C-5 present the interpreted in-situ strength curves for the materials which constitute the switchyard slopes. The curves for terrace deposit soils (Figs. C-2, C-3, C-4) represent the laboratory strength curves reduced by a correction factor of 0.8.* This value is thought to be conservative, because of the very high density of the terrace materials and the fact that they are not saturated. The anisotropic curves shown on Fig. C-4 for local weaker materials were drawn by increasing the isotropic curve an amount proportional to the average anisotropic increase of the other terrace deposit materials tested (shown in Figs. C-2 and C-3). For example, at N=10 stress cycles:

For terrace Sands;

for a change of $K_c' = 1.0$ to 2.0

*Correction factor, C_r, defined by Seed & Idriss (1971), ref. 19.

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the corresponding change in $\frac{\tau_{cy}}{\sigma_{fc}}$ is from 0.72 to 1.33

which is an increase of $\frac{1.33}{0.72} = 1.85$

For terrace clays:

for a change of $K_c' = 1.0$ to 2.0

the corresponding change in $\frac{\tau_{cy}}{\sigma_{fc}}$ is from 1.14 to 1.51

which is an increase of $\frac{1.51}{1.14} = 1.32$

The average increase is $\frac{1.85 + 1.32}{2} = 1.53$; therefore, at N = 10 cycles, for $K_c' = 2.0+$, the curve was drawn 1.53 times the $K_c' = 1.0$ curve for the local weaker materials in Fig. C-4.

No dynamic strength tests were made on partially saturated samples of the San Mateo Formation Sand, however dynamic tests have been made on saturated samples. Those results are presented in our report entitled *Liquefaction Evaluation for the Proposed Units 2 and 3, San Onofre Generating Station, San Onofre, California,* dated 22 Jan 74. Those dynamic strength curves are reproduced on Fig. C-5. They were used for this study for San Mateo Formation dynamic strength. Because the local groundwater conditions minimize the possibility of saturation (above elevation 5 ft), use of these data for partially saturated dynamic strength is thought to be very conservative.

C-4 Modulus and Damping Values

As discussed in Appendix B, dynamic strength test data

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were also used to calculate strain-dependent modulus and damping values, for use in finite-element analyses. The calculations indicate that 1) the sandy terrace deposit soils are slightly stiffer than previously assumed, 2) the stiffnesses previously used for clayey terrace deposit soils are appropriate, and 3) the damping values previously used for both sandy and clayey terrace soils are appropriate. Plots of the modulus and damping relationships used are given on Figs. C-6 through C-11.

C-5 Soil Density

Moisture and density determination have been made from 1) samples obtained from borings, and 2) field density (sand cone) tests. Based on these data, as well as information from previous studies,* the wet densities given below were used for the analyses:

Material	γm (pcf)
Upper Terrace Deposit (clayey soils)	138.
Lower Terrace Deposit (sandy soils)	125.

Sand cone tests made in San Mateo Formation Sand indicate an average in-situ dry density of approximately 120 to 125 pcf. Boring log data indicate the moisture content of this material varies from about 2% to 16%. Based on these data, an average

*Ref 21.

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in-situ wet density of 130 pcf was estimated. This value was used in the analyses.

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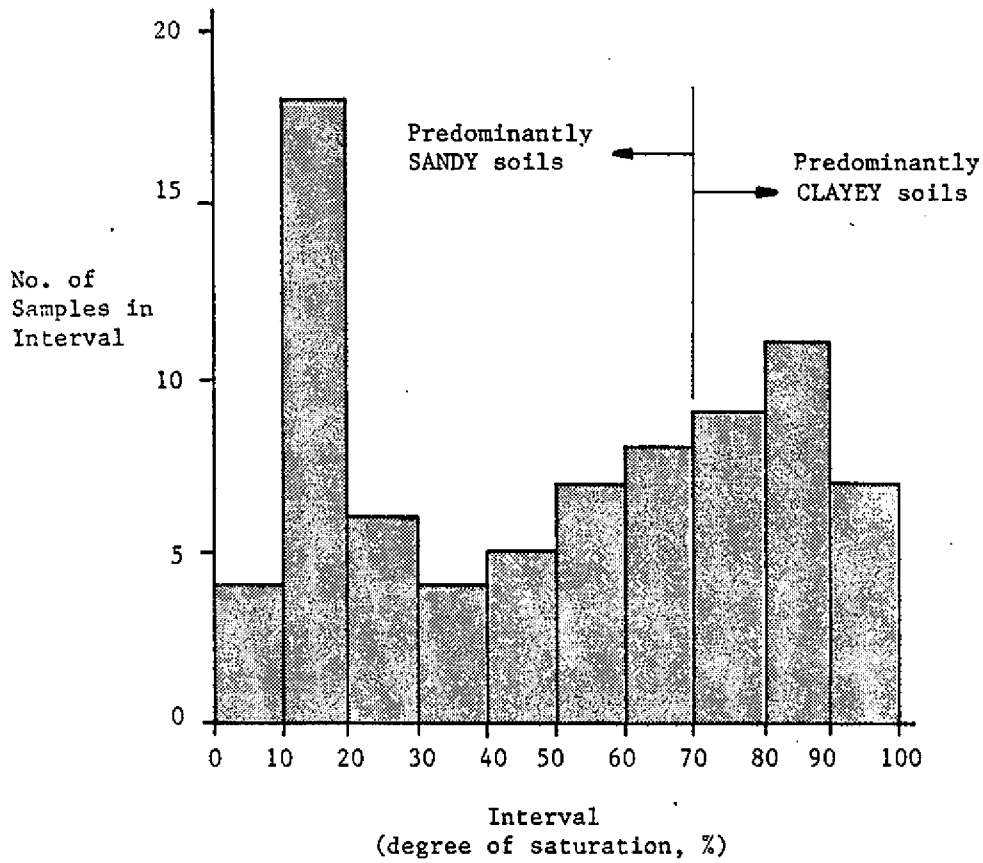

NOTES:

1) 79 samples analyzed
2) Average degree of saturation is 50%

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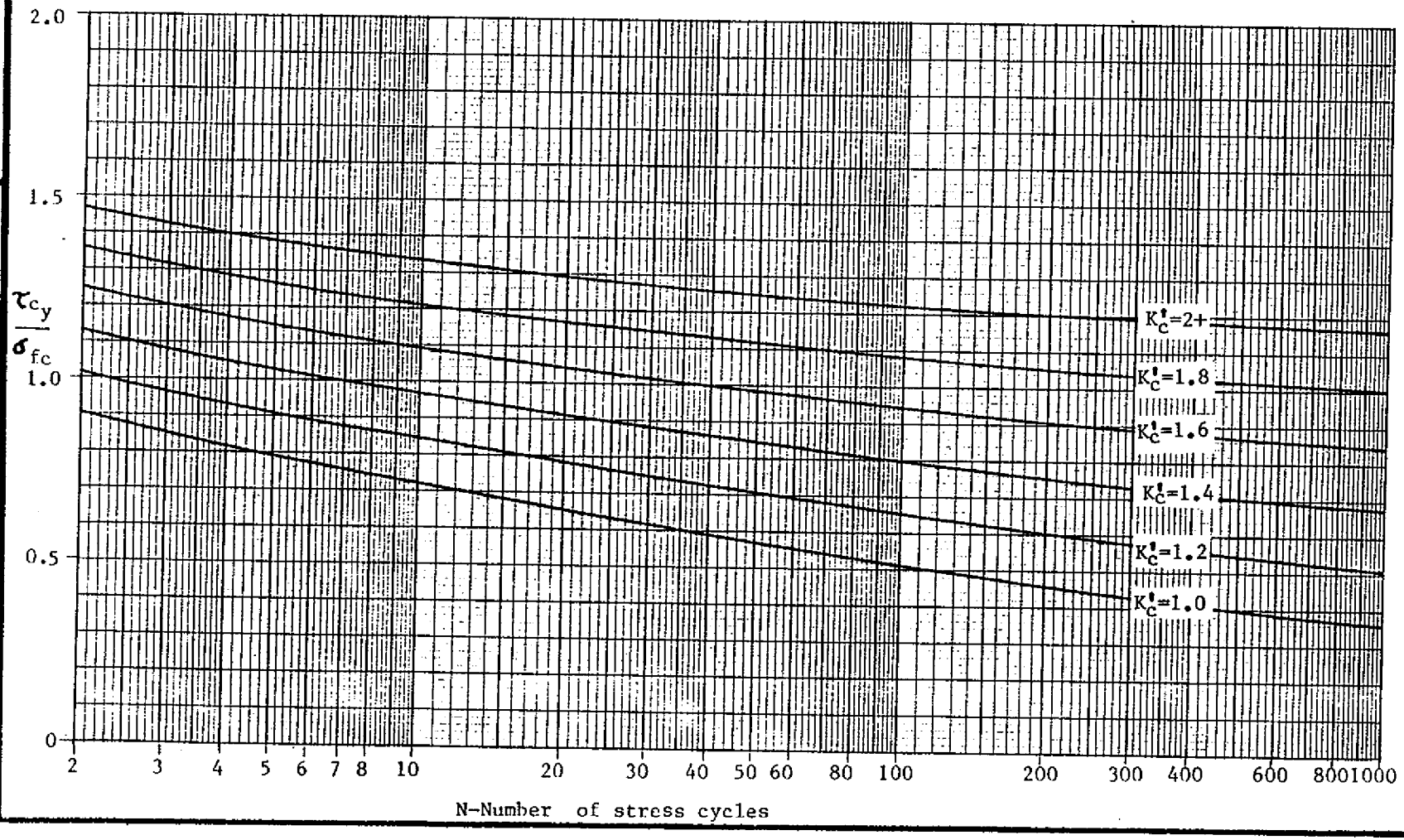
Field strength curves

Lower terrace deposit - SANDY soils



Project: SONGS SLOPE STABILITY

Job Number: B469A4

DYNAMIC STRENGTH
SANDY TERRACE DEPOSIT SOILS

Fig. C-2

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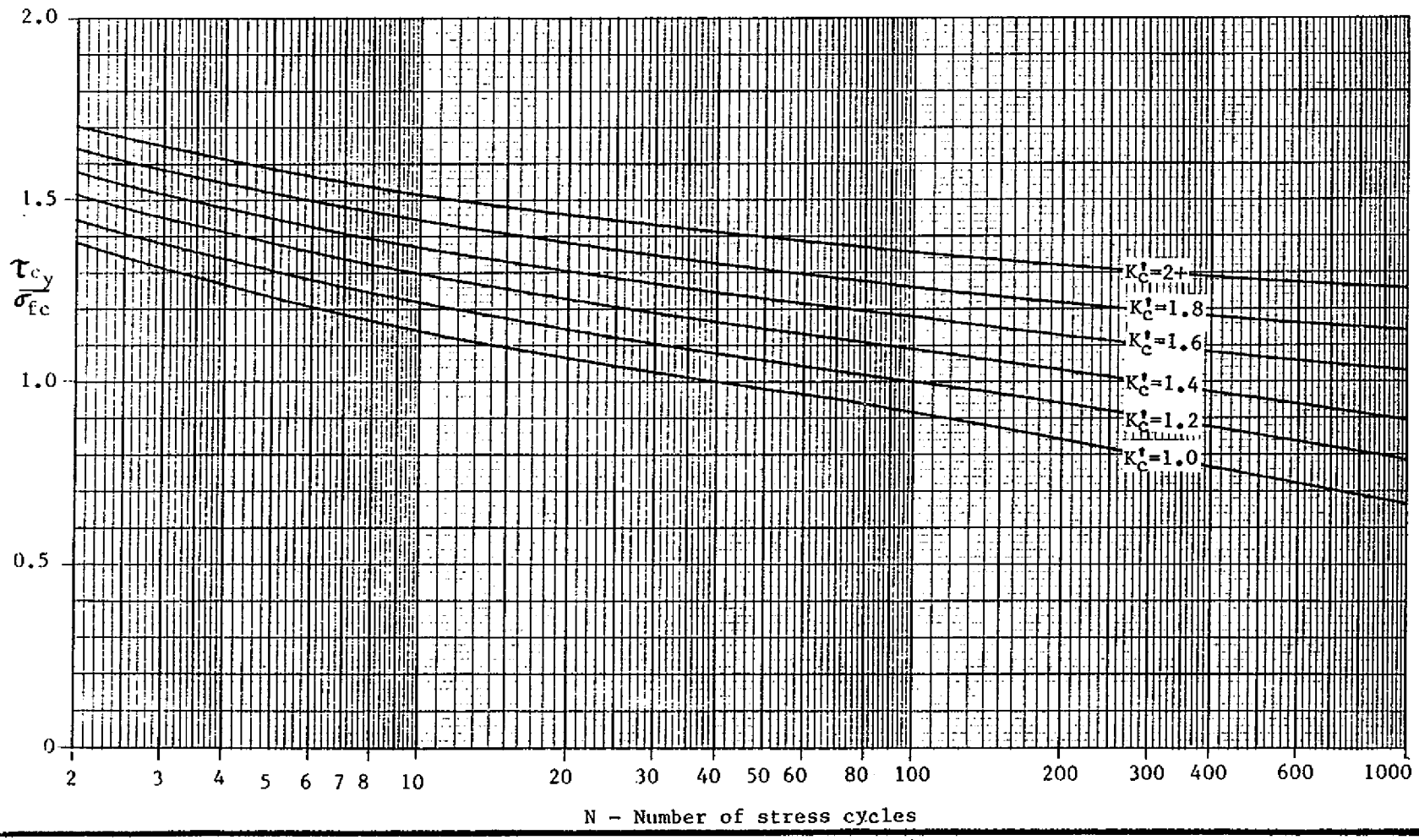
Field strength curves
Dynamic strength of upper
Terrace deposit - CLAYEY soils



Project: SONGS SLOPE STABILITY
Job Number: B469A4

DYNAMIC STRENGTH
CLAYEY TERRACE DEPOSIT SOILS

Fig. C-3

WOODWARD-McNEILL & ASSOCIATES

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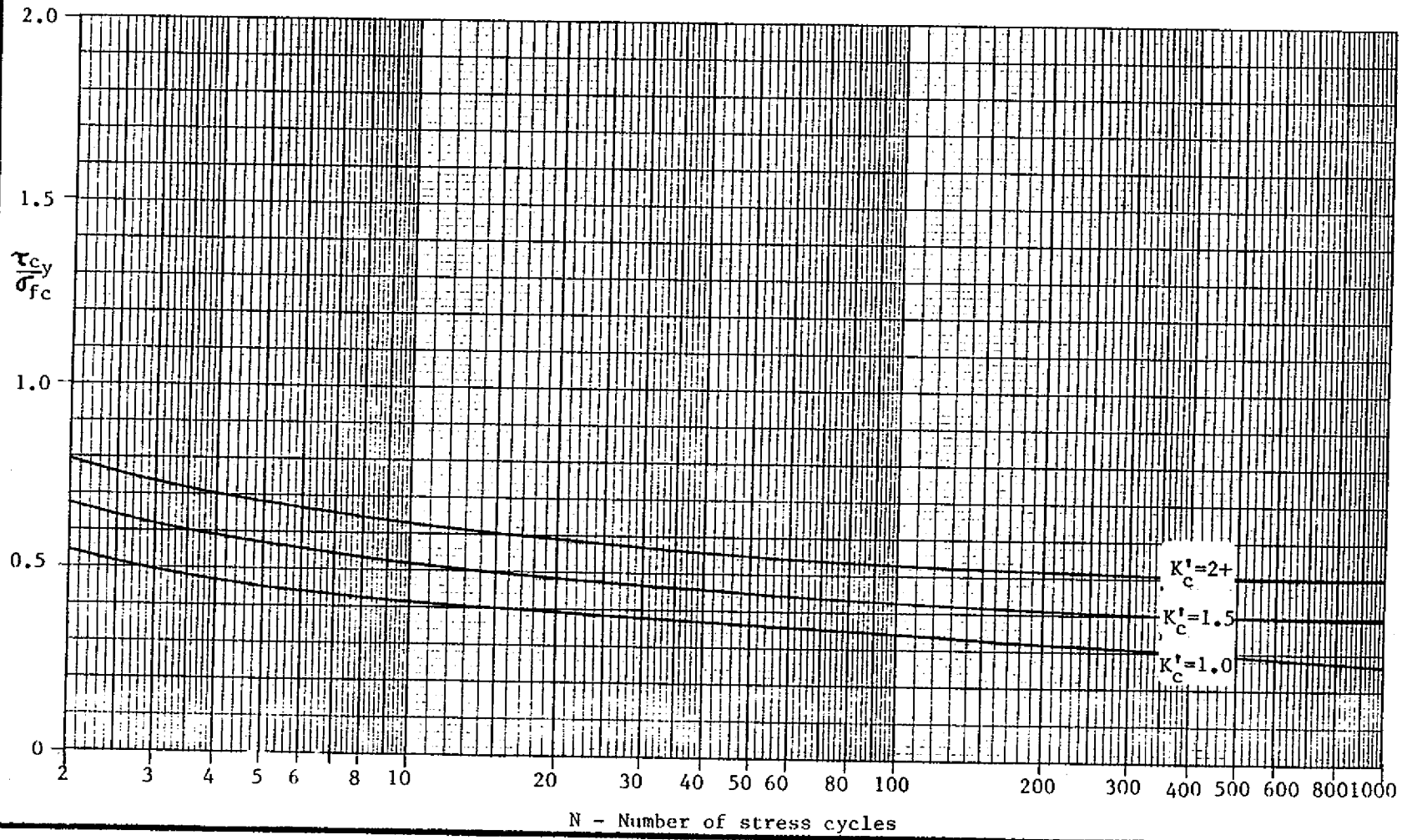
Field strength curves

Weaker lenses - terrace deposit materials



Project: SONGS SLOPE STABILITY

Job Number: B469A4

DYNAMIC STRENGTH

WEAKER SOIL LENSES - TERRACE DEPOSIT

Fig. C-4

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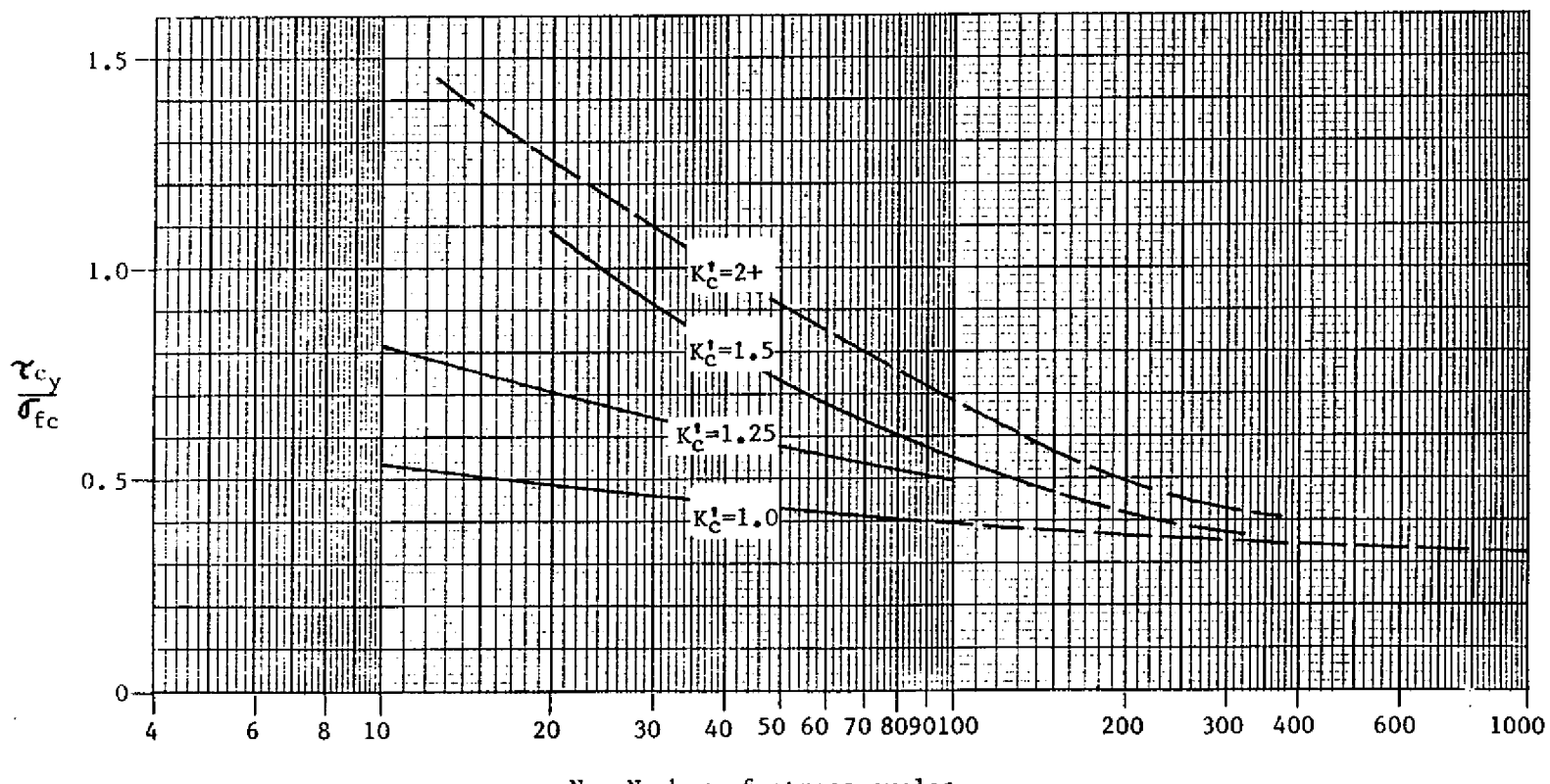
Field dynamic strength curves
San Mateo SAND

NOTES:

1) Curves for K_c'=1.0, 1.25, 1.5 are for Saturated Tests, presented in Liquefaction Evaluation Report, dated 22 Jan. 74.

2) Curve for K_c'=2+ is conservative extrapolation.

3) Dashed lines are extrapolated



Project: SONGS SLOPE STABILITY
Job Number: B469.A4

DYNAMIC STRENGTH
SAN MATEO SAND

Fig. C-5

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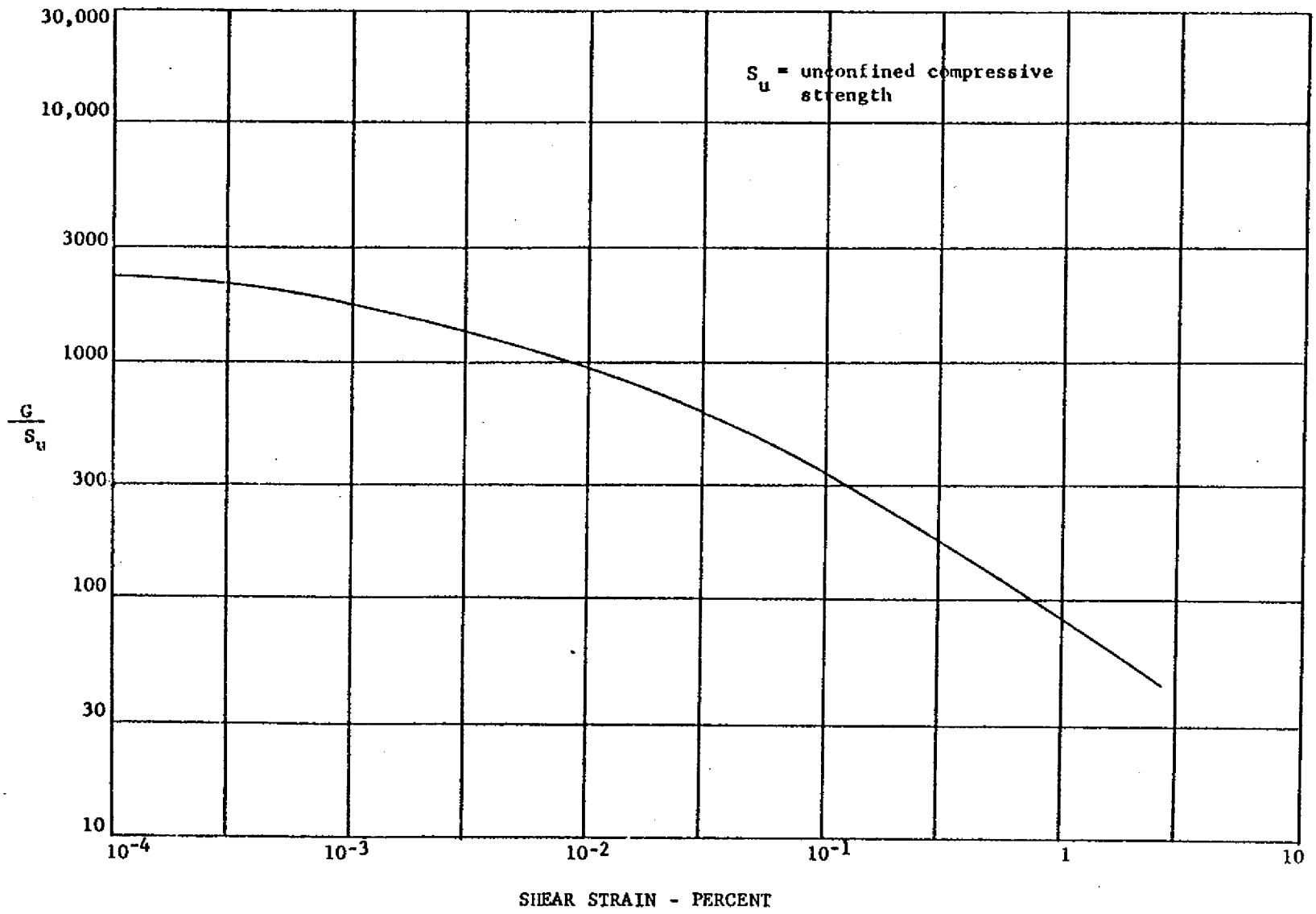

Project: SONGS SLOPE STABILITY Job Number: B469A3	VARIATION OF SHEAR MODULUS WITH STRAIN FOR CLAYEY TERRACE DEPOSIT SOILS	Fig. C-6

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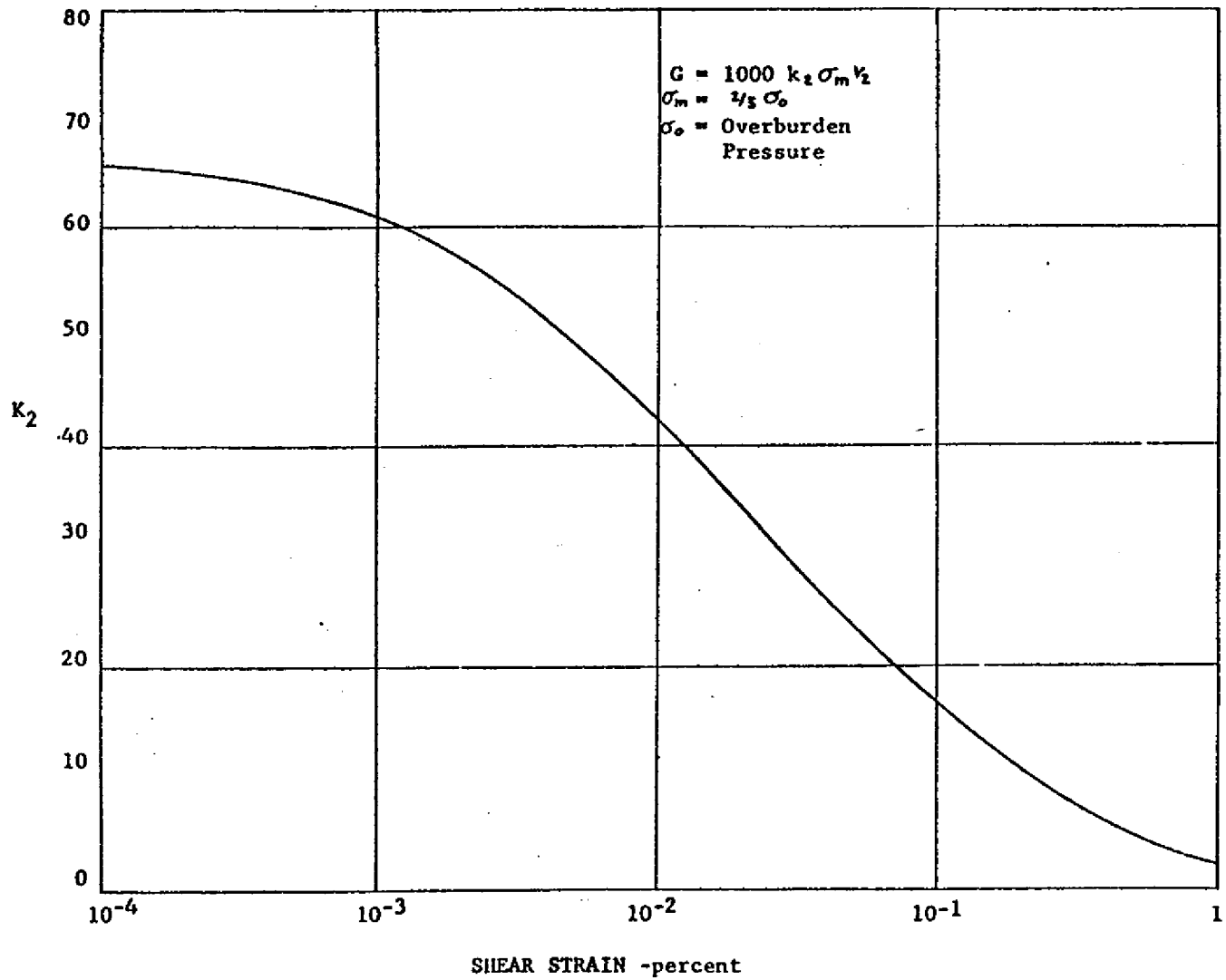
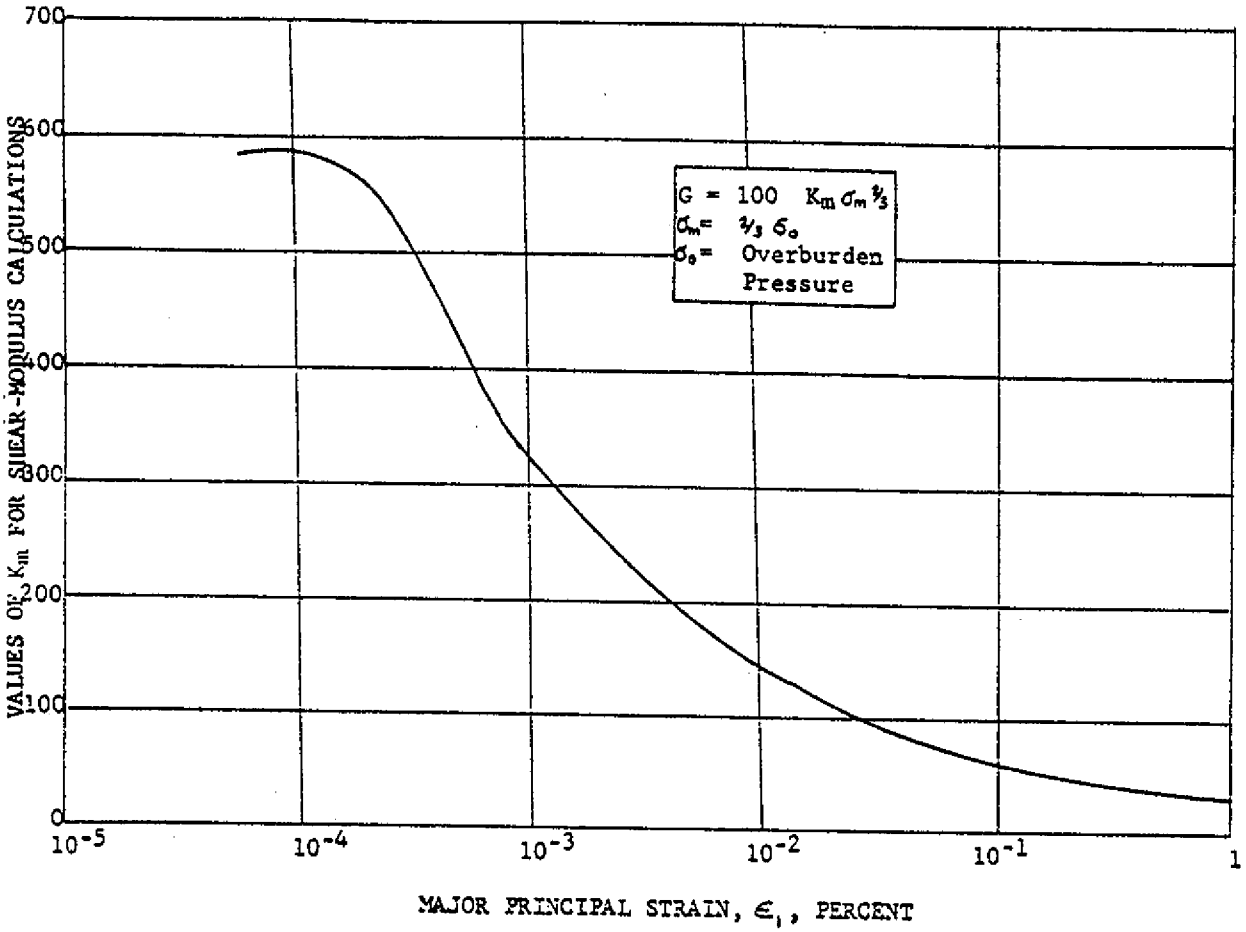


SHEAR MODULI OF SANDY TERRACE DEPOSIT SOILS

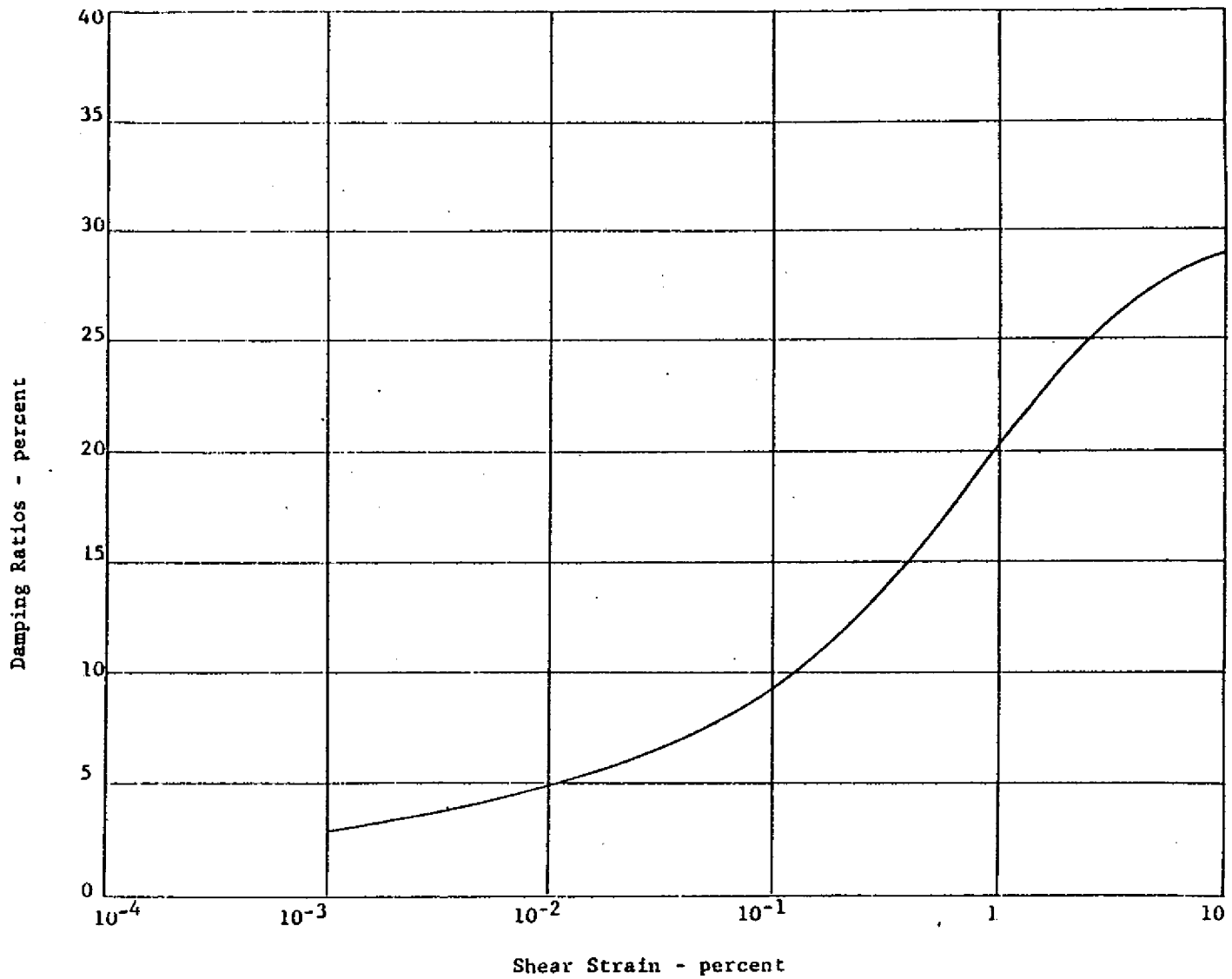
Project: SONGS SLOPE STABILITY Job Number: B469A3	VARIATION OF SHEAR MODULUS WITH STRAIN FOR TERRACE DEPOSIT SAND	Fig. C-7

Amended: April 2009 TL: E048000



Project: SONGS SLOPE STABILITY Job Number: B469A3	VARIATION OF SHEAR MODULUS WITH STRAIN FOR SAN MATEO FORMATION SAND	Fig. C-8

Amended: April 2009 TL: E048000



Project: SONGS SLOPE STABILITY Job Number: B469A3	VARIATION OF DAMPING RATIO WITH STRAIN FOR CLAYEY TERRACE DEPOSIT SOIL	Fig. C-9

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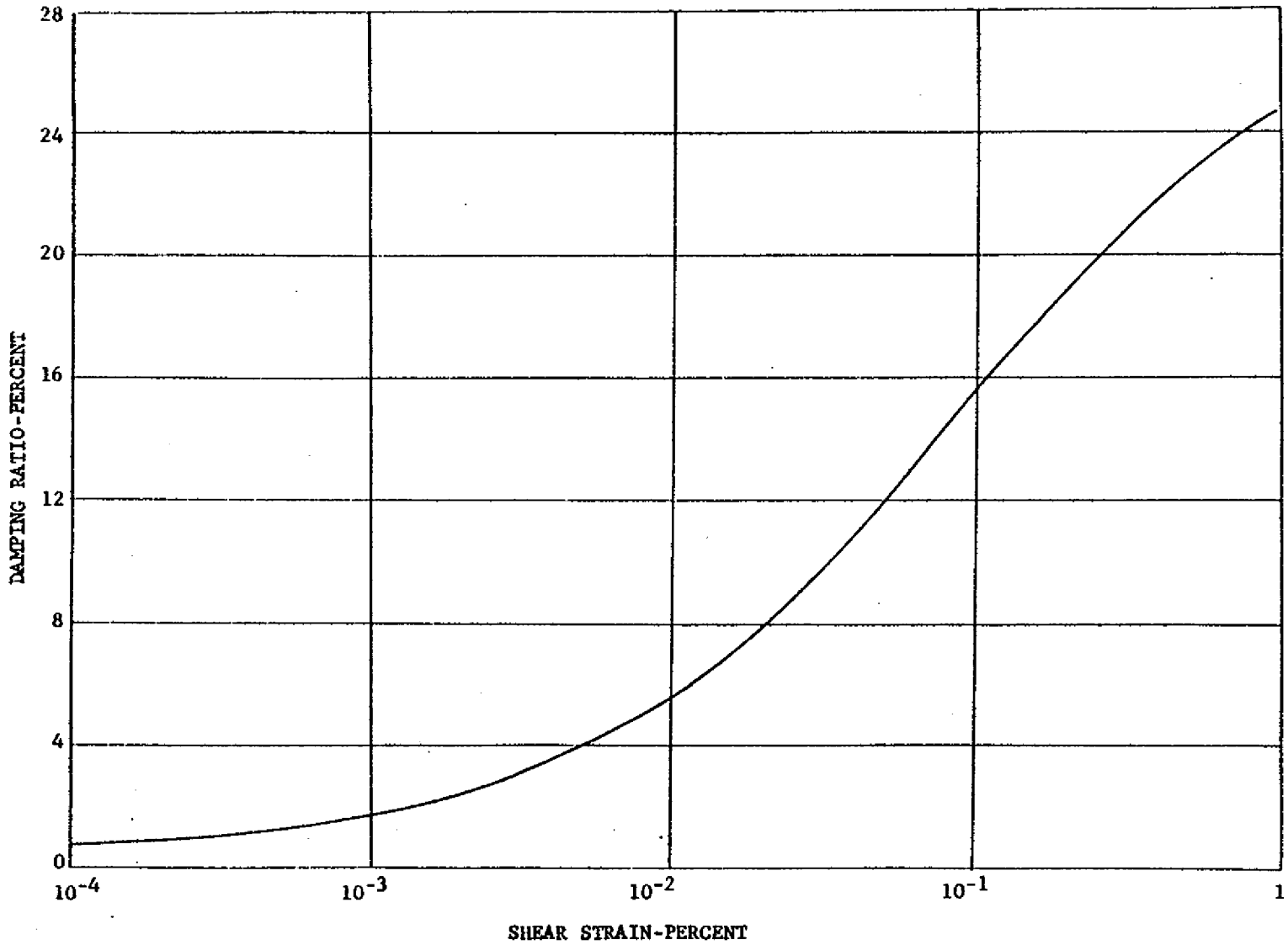
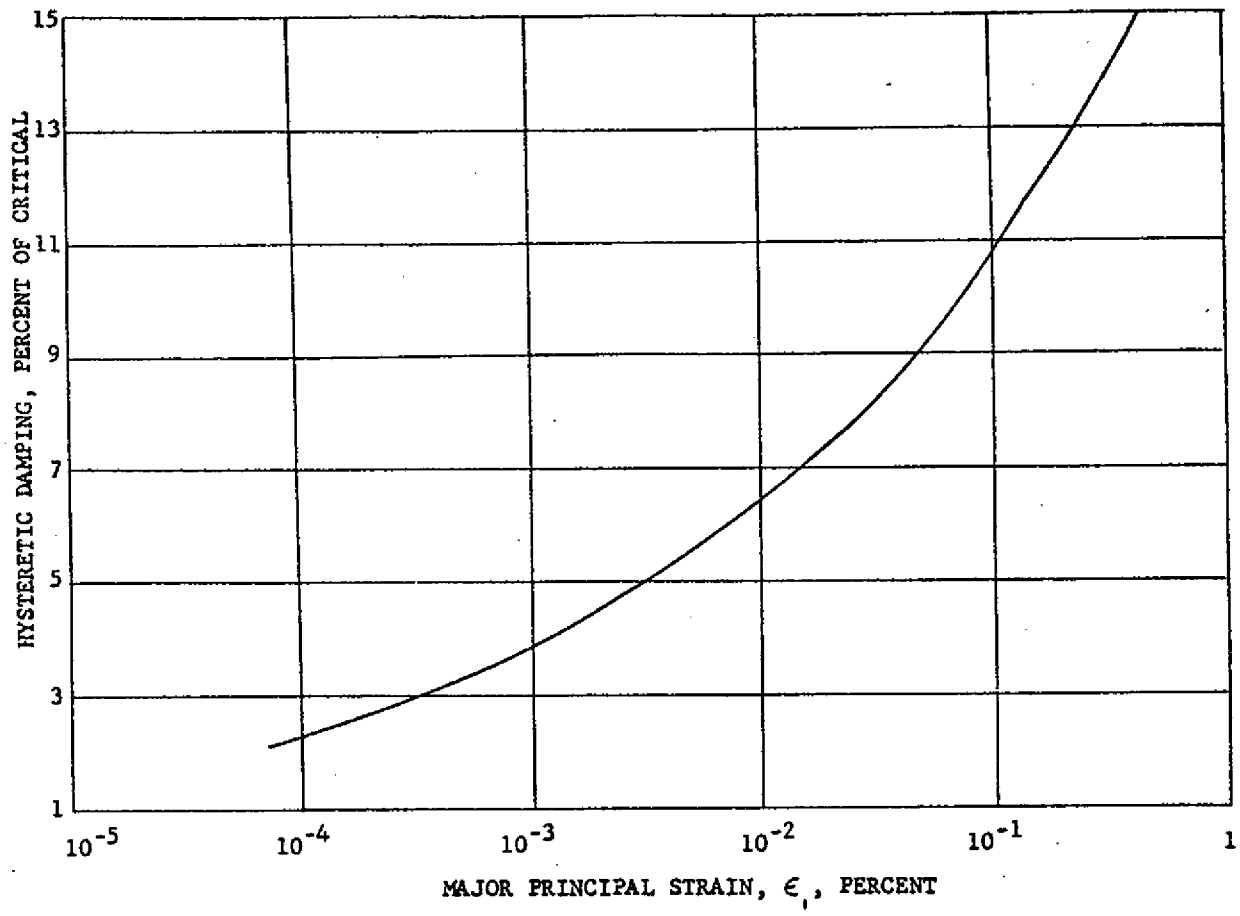


Project: SONGS SLOPE STABILITY Job Number: B469A3	VARIATION OF DAMPING RATIO WITH STRAIN FOR SANDY TERRACE DEPOSIT SOILS	Fig. C-10

Amended: April 2009 TL: E048000



Project: SONGS SLOPE STABILITY Job Number: B469A3	VARIATION OF DAMPING RATIO WITH STRAIN FOR SAN MATEO FORMATION SAND	Fig. C-11

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APPENDIX D

FINITE ELEMENT STUDIES

D-1 Mesh Construction

A finite-element mesh of the proposed switchyard slope configuration was developed with a suitable number of elements to represent the slope-foundation system. Specifically, the mesh, shown on Fig. D-1, was developed to represent the various soil zones and groundwater conditions at the site. The model was then used for static and dynamic analyses, as discussed below.

D-2 Static Finite-Element Analysis

For estimation of pre-earthquake stress conditions, a gravity turn-on static finite-element computer program was used. This program (LOCKS), developed at the University of California, Berkeley, outputs normal and shear stresses acting on each element in the model due to the weight of the constituent soils and their stiffnesses. The output stresses were then used in the stability evaluation as discussed in Appendix E.

D-3 Dynamic Finite-Element Analysis

The finite-element computer program (QUAD 4) used to determine dynamic normal and shear stresses induced in each element of the model (by the input base motion) was also developed at the University of California, Berkeley. Details of the computer program are presented in Report No. EERC 73-16,

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entitled *QUAD 4, a Computer Program for Evaluating the Seismic Response of Soil Structures by Variable Damping Finite-Element Procedures*, by the College of Engineering of the University of California, Berkeley, dated July 1973.

Utilization of this program involved the following procedure:

1. The slope-foundation system was divided into a suitable number of elements to represent the sytem, as outlined in Section D-1. The mesh was extended to a sufficient distance from the slopes to minimize the influence of fixed vertical boundaries on the response values in the vicinity of the slope.
2. The input base motion (Section D-4) is applied at the bottom of the model and response values throughout the model are computed.
3. The computer program for the analyses takes into account the strain dependency of moduli and damping by obtaining new values of these parameters for strain values computed by using initial estimated values. The iteration is done for a desired number of cycles to obtain values of moduli and damping (Appendix C) which are compatible with the strains developed in the elements.
4. The output from the computer program consists of normal and shear stresses on each element, nodal

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point displacements, velocities, and accelerations caused by the given input base motion.

The output dynamic stresses were used to evaluate slope stability, as discussed in Appendix E.

D-4 Input Base Motion

The synthesized acceleration time history of ground motion used for input at the base of the finite-element model is shown on Fig. D-2. This is the same base motion as was used to represent the DBE for the previous dynamic evaluation, and details of its use are presented in that report (Ref. 21).

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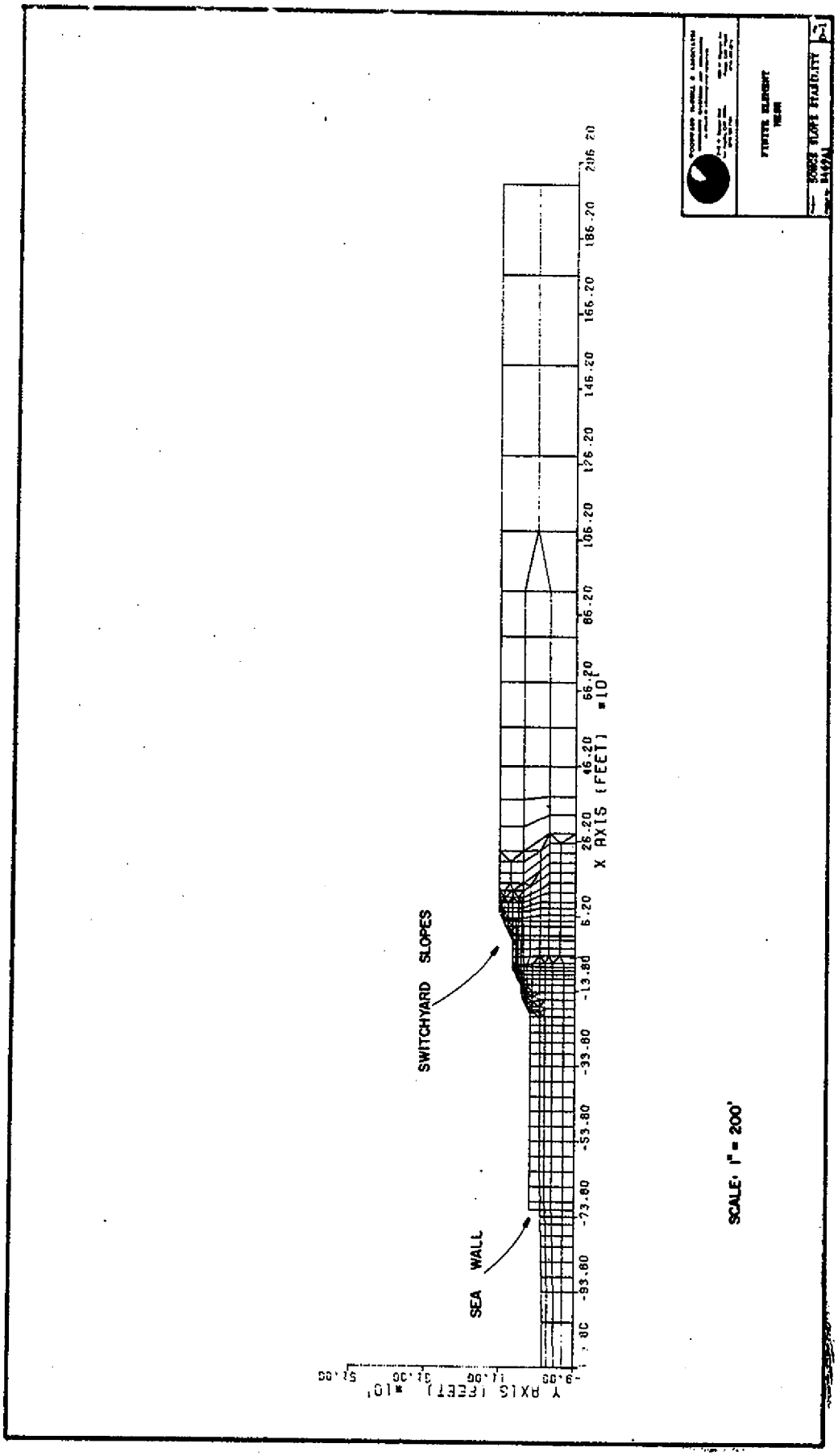
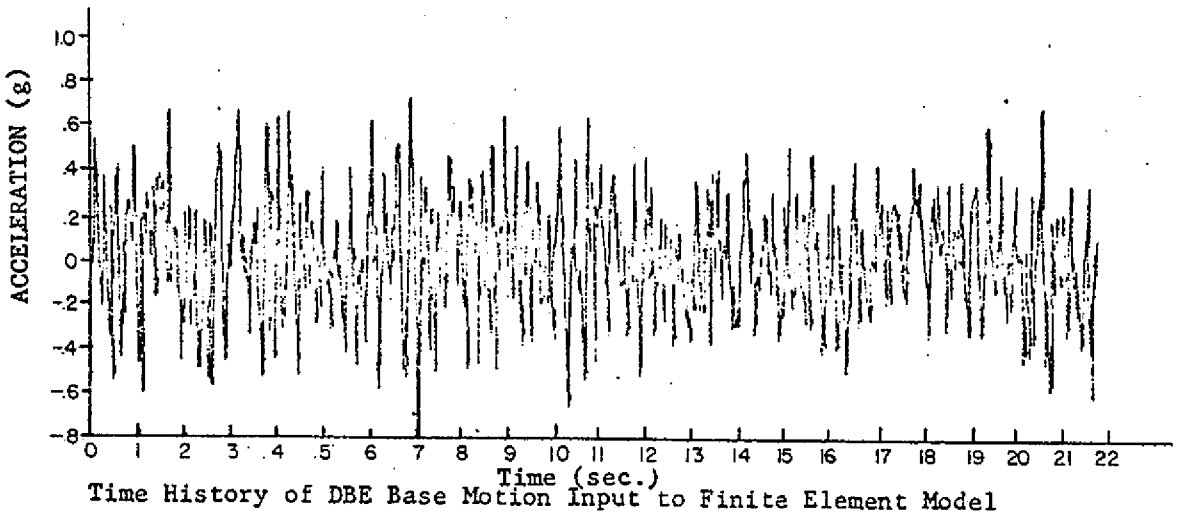

SWITCHYARD SLOPES
SEA WALL
SCALE: 1" = 200'
X AXIS (FEET) *10'
Y AXIS (FEET) *10'



Time History of DBE Base Motion Input to Finite Element Model

Maximum acceleration = 0.86g

Project: SONGS SLOPE STABILITY Job Number: 3489A4	SYNTHESIZED DBE BASE MOTION TIME HISTORY	Fig. D-2

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APPENDIX E

STABILITY EVALUATION

E-1 General

The previous study made of dynamic slope stability utilized assumed values for dynamic strength parameters, ϕ and c, (friction angle and cohesion) based on correlation with static soil properties and on correlation with dynamic tests of materials from other sites. The dynamic laboratory tests made for the present study facilitated a more accurate determination of the dynamic strengths of the terrace deposit soils. The laboratory test data generated do not facilitate analysis in terms of ϕ and c however, therefore analyses were made to determine the number of equivalent significant stress cycles induced in the soil profile by the DBE, and to compare this to the dynamic soil strength.

The basic procedure used for stability evaluation was 1) to perform preliminary, very conservative analyses (summarized on Table E-1) to size the problem and locate areas of potential instability for further consideration, then 2) to more realistically (although still somewhat conservatively) examine the stability of those areas of potential instability. These analyses are discussed below.

E-2 Stress Cycle Analysis

Pre-earthquake stress conditions were determined by static finite element methods (Appendix D). Values of K_c' (field

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consolidation stress ratio) were calculated for each finite element in order to determine the appropriate dynamic strength curve to use for stability evaluation. Earthquake induced shear stress (τ_{max}) were taken from the dynamic finite element analysis (Appendix D), divided by initial overburden pressures (σ_{fc}), and used to determine the number of stress applications (N) required to cause failure (10% strain). The value of N was then compared to the number of stress applications induced by the DBE (at a given stress level) to determine the relative stability of each finite element in the slope model. Table E-1 presents a summary of this information for each element, based on a stress level of $\frac{\tau_{max}}{\sigma_{fc}}$ in the finite element model are shown on Fig. E-1. Review of the data in Table E-1 shows that even at the maximum stress level (τ_{max} occurs only once, instantaneously) most elements require over 1000 stress applications to cause failure or overstressing.

Previous studies have indicated that the DBE produces approximately 77 significant stress cycles in the free field at a stress level of 65% of $\frac{\tau_{max}}{\sigma_{fc}}$ (ref. 22). Because the present study required the use of a time-history of 22 sec duration to represent the DBE, analyses were made of the number of significant stress cycles produced in the free field for comparative purposes. A pulse spectrum of the shear-stress time history used for this comparison is presented

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on Fig. E-2. The equivalent number of significant stress cycles at the 65% stress level were calculated by the method outlined by Lee and Chan (ref. 10). A summary of this data is presented on Table E-2. These data indicate that the 22 sec. input base motion produces 21 equivalent significant stress cycles at a stress level of 65% of τ_{max}. Thus, in the free field, 21 cycles for this analysis are equivalent to 77 cycles of the DBE (at 65% τ_{max}). Analysis of elements in the slope portion of the model indicated approximately the same number of equivalent significant stress cycles were produced as in the free field.

For each element listed in Table E-1 in which failure or overstressing is indicated in less than 50 cycles (at a stress level of τ_{max}) more detailed studies were made. A summary of these data is presented on Table E-3. Analysis was made of the number of equivalent significant stress cycles at the 65% stress level. For example (see Table E-3), for element 255 (location shown on Fig E-1):

$$\frac{.65\tau_{max}}{\sigma_{fc}} = 0.33$$

$$K_c' = 1.03$$

Given these data, refer to the dynamic strength curve in Appendix C (Fig. C-4), for the appropriate material, and a value of 150 is read for N. This is the number of cycles (at this

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stress level) which would be required to cause failure or overstressing. Since the DBE will produce no more than about 80 stress cycles, it is assumed that this element will be stable. This analysis was made for each element presented in Table E-3, and the results are summarized schematically on Fig. E-3. Any element for which this analysis indicates failure will occur in less than 80 stress applications has been assumed unstable or overstressed.

For the purposes of this study, analyses were made assuming that the sandy portion of the terrace deposit could contain weaker lenses (with dynamic strengths shown in Appendix C, Fig. C-4) as well as the more representative, stiffer materials (dynamic strength shown in Appendix C, Fig. C-2). The results shown on Fig. E-3 reflect our understanding of the in-situ soil conditions; i.e., weaker lenses are horizontal, and at most only a few feet thick. Calculations were also made of the factor of safety of each element (assuming the most representative soil conditions). These calculations involved a comparison of the appropriate dynamic shear strength (taken at N = 80 stress applications) to the earthquake-induced shear stress (65% of τ_{max}, which corresponds to 80 stress applications, as discussed above). The results of this analysis are presented on Fig. E-4.

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TABLE E-1

SUMMARY OF PRELIMINARY STABILITY EVALUATION DATA FOR ALL SLOPE ELEMENTS

Element No.	Material Type	K_c'	σ_o (psf)	τ_{max} (psf)	$\frac{\tau_{cy}}{\sigma_{fc}}$ $(=\frac{\tau_{max}}{\sigma_o})$	N @ $\frac{\tau_{cy}}{\sigma_{fc}}$ (stress cycles)	Reference Fig. No. for Soil Strength
107	San Mateo	1.35	1736	896	.52	120	C-5
108	"	1.38	4196	2030	.48	140	"
112	"	4.53	812	847	1.04	35	"
113	"	1.95	1925	776	.40	350	"
114	"	1.50	2808	1458	.52	120	"
120	"	4.20	873	179	.22	1000+	"
121	"	1.74	2867	799	.28	"	"
123	"	4.82	892	234	.26	"	"
124	"	2.30	1447	491	.34	"	"
125	"	1.71	3301	761	.23	"	"
127	"	4.22	667	85	.13	"	"
128	"	2.68	1423	325	.23	"	"
129	"	1.62	2349	484	.21	"	"
130	"	1.79	3423	689	.20	"	"
131	"	1.42	4492	1067	.24	"	"
137	Terrace Sand	4.94	439	69	.16	"	C-2 or C-4
138	San Mateo	4.34	738	86	.11	"	C-5
139	"	2.22	855	74	.09	"	"
140	"	2.08	1915	2091	1.09	32	"
141	"	1.45	3022	337	.11	1000+	"
142	"	1.60	4333	975	.23	"	"
143	Terrace Sand	1.20	269	94	.34	"	C-2 or C-4
144	"	1.92	488	100	.20	"	"
145	San Mateo	1.70	1195	95	.08	"	C-5
146	"	1.78	1626	255	.16	"	"
147	"	1.83	2306	270	.12	"	"
148	"	1.46	2897	755	.26	"	"
149	"	1.36	4745	1001	.21	"	"
150	"	1.44	5214	816	.16	"	"

NOTE: See Fig. E-1 for locations of elements.

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TABLE E-1 (Cont'd)

Element No.	Material Type	K_c'	σ_o (psf)	τ_{max} (psf)	$\frac{\tau_{cy}}{\sigma_{fc}}$ $(=\frac{\tau_{max}}{\sigma_o})$	N @ $\frac{\tau_{cy}}{\sigma_{fc}}$ (stress cycles)	Reference Fig. No. for Soil Strength
155	Terrace Sand	2.55	464	43	.09	1000+	C-2 or C-4
156	"	1.75	942	102	.10	"	"
157	San Mateo	1.47	1533	186	.12	"	C-5
158	"	1.48	2085	488	.23	"	"
159	"	1.49	3153	693	.22	"	"
160	"	1.39	3805	1419	.37	250	"
161	"	1.48	5332	802	.15	1000+	"
166	Terrace Sand	5.83	439	88	.20	"	C-2 or C-4
167	"	2.88	971	151	.16	"	"
168	"	2.08	1423	645	.45	"	"
169	San Mateo	1.83	2060	344	.17	"	C-5
170	Terrace Sand	2.66	1033	311	.30	"	C-2 or C-4
171	"	2.09	1634	628	.38	"	"
172	San Mateo	1.66	2711	1481	.55	110	C-5
173	"	1.65	2708	1053	.39	250	"
174	"	1.47	4034	1515	.38	300	"
175	"	1.38	6247	1440	.23	1000+	"
180	Terrace Sand	5.74	556	152	.27	"	C-2 or C-4
181	"	3.70	514	133	.26	"	"
182	"	2.26	1333	343	.26	"	"
183	"	1.89	1909	814	.43	"	"
184	"	1.69	2380	1270	.53	1000+ or 16	"
185	San Mateo	1.54	3151	637	.20	1000+	C-5
186	"	1.39	4621	585	.13	"	"
192	Terrace Sand	5.32	464	66	.14	"	C-2 or C-4
193	"	3.26	642	78	.12	"	"
194	"	2.28	1120	202	.18	"	"
195	"	1.74	1696	448	.29	"	"
196	"	1.66	1961	766	.39	"	"
197	"	1.83	2301	1701	.74	1000+ or 2	"
198	"	1.62	2849	2134	.75	"	"
199	San Mateo	1.48	3597	1436	.40	230	C-5
200	"	1.35	5066	966	.19	1000+	"
206	Terrace Sand	4.87	376	52	.14	"	C-2 or C-4

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TABLE E-1 (Cont'd)

Element No.	Material Type	K_c'	σ_o (psf)	τ_{max} (psf)	$\frac{\tau_{cy}}{\sigma_{fc}}$ $(=\frac{\tau_{max}}{\sigma_o})$	N @ $\frac{\tau_{cy}}{\sigma_{fc}}$ (stress cycles)	Reference Fig. No. for Soil Strength
207	Terrace Sand	1.95	671	96	.14	1000+	C-2 or C-4
208	"	1.60	398	75	.19	"	"
209	"	1.68	1107	205	.19	"	"
210	"	1.55	1345	415	.31	"	"
211	"	1.49	1768	875	.49	1000+ or 15	"
212	"	1.36	2164	1004	.46	1000+ or 25	"
213	"	1.42	2888	2527	.88	30 or 1	"
214	San Mateo	1.50	3711	1475	.40	230	C-5
215	"	1.38	5432	1671	.31	1000+	"
216	"	1.25	7901	2812	.35	330	"
221	Terrace Sand	1.96	393	109	.28	1000+	C-2 or C-4
222	"	1.10	631	219	.35	1000+ or 70	"
223	"	1.15	1739	478	.39	850 or 65	"
224	"	1.08	1458	933	.64	50 or 1.5	"
225	"	1.17	1985	1279	.64	50 or 1.5	"
226	"	1.25	2239	1598	.68	120 or 1.5	"
227	"	1.27	2861	2741	.96	4 or 0.5	"
228	San Mateo	1.37	3762	976	.26	1000+	C-5
229	"	1.66	4979	2110	.42	230	"
230	"	1.29	9057	2584	.29	1000+	"
235	Terrace Sand	1.12	471	177	.38	1000+ or 60	C-2 or C-4
236	"	1.02	667	223	.33	1000+ or 40	"
237	"	1.11	1321	783	.59	90 or 2	"
238	"	1.22	613	173	.28	1000+	"
239	"	1.09	1365	276	.20	"	"
240	"	1.09	1671	996	.60	75 or 2	"
241	"	1.03	2219	2226	1.00	1 or 0.5	"
242	"	1.00	3122	2449	.78	5.5 or 0.5	C-2 or C-4
243	San Mateo	1.06	4506	1354	.30	1000+	C-5
244	"	1.02	6671	2831	.42	60	"
245	"	1.00	8450	3201	.38	140	"
252	Terrace Sand	1.31	603	614	1.00	4 or 0.5	C-2 or C-4
253	"	1.15	1541	1519	.99	2 or 0.5	"

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TABLE E-1 (Cont'd)

Element No.	Material Type	K_c'	σ_o (psf)	τ_{max} (psf)	$\frac{\tau_{cy}}{\sigma_{fc}}$ $(=\frac{\tau_{max}}{\sigma_o})$	N @ $\frac{\tau_{cy}}{\sigma_{fc}}$ (stress cycles)	Reference Fig. No. for Soil Strength
254	Terrace Sand	1.05	2441	2331	.95	2 or 0.5	C-2 or C-4
255	"	1.03	3432	1701	.50	110 or 3	"
256	San Mateo	1.14	5121	603	.12	1000+	C-5
257	"	1.17	8164	4474	.54	40	"
261	Terrace Sand	1.23	614	760	1.24	1 or 0.5	C-2 or C-4
262	"	1.33	1590	1585	1.00	4 or 0.5	"
263	"	1.31	429	203	.47	1000+ or 15	"
264	"	1.14	1014	966	.95	2.5 or 0.5	"
265	"	1.28	1914	1428	.75	70 or 1	"
266	"	1.29	1702	1805	1.06	2.5 or 0.5	"
267	"	1.28	2762	2290	.83	20 or 0.5	"
268	"	1.28	3816	2102	.55	1000+ or 3	"
269	San Mateo	1.26	5605	2511	.45	150	C-5
270	"	1.24	8660	4619	.53	75	"
274	Terrace Clay	3.32	497	1849	3.72	0.5	C-3
275	Terrace Sand	2.20	1347	1397	1.04	1000+ or 1	C-2 or C-4
276	"	1.72	2549	1789	.70	1000+ or 2.5	"
277	"	1.58	3359	2578	.77	1000+ or 1.5	"
278	"	1.47	4383	345	.08	1000+	"
279	San Mateo	1.35	6137	2169	.35	400	C-5
280	"	1.27	9172	4352	.47	150	"
284	Terrace Clay	4.48	567	2502	4.40	0.5	C-3
285	"	2.46	1004	1929	1.92	0.5	"
286	Terrace Sand	2.16	1814	1660	.92	1000+ or 1	C-2 or C-4
287	Terrace Clay	5.26	534	410	.77	1000+	C-3
288	"	3.01	1067	2157	2.02	0.5	"
289	"	1.76	1855	2019	1.08	1000+	"
290	Terrace Sand	1.74	2985	2217	.74	1000+ or 2	C-2 or C-4
291	"	1.74	2957	2130	.72	1000+ or 2	"
292	"	1.66	3570	2405	.67	1000+ or 3	"
293	"	1.54	4462	2545	.57	1000+ or 6	"
294	"	1.47	5295	1937	.37	1000+	"
295	San Mateo	1.36	6947	2165	.31	"	C-5

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TABLE E-1 (Cont'd)

Element No.	Material Type	K_c'	σ_o (psf)	τ_{max} (psf)	$\frac{\tau_{cy}}{\sigma_{fc}}$ (= $\frac{\tau_{max}}{\sigma_o}$)	N @ $\frac{\tau_{cy}}{\sigma_{fc}}$ (stress cycles)	Reference Fig. No. for Soil Strength
296	San Mateo	1.27	9853	3888	.39	250	C-5
300	Terrace Clay	5.0+	365	305	.84	1000+	C-3
301	"	5.0+	578	455	.78	"	"
302	"	2.48	1090	379	.35	"	"
303	"	1.86	1973	2084	1.06	"	"
304	"	1.52	2767	1873	.68	"	"
305	Terrace Sand	1.55	3637	2425	.67	1000+ or 2.5	C-2 or C-4
306	"	1.43	4639	2769	.60	"	"
307	"	1.39	5371	2629	.49	1000+ or 10	"
308	"	1.38	6184	2900	.47	1000+ or 15	"
309	San Mateo	1.31	7799	2642	.34	1000+	C-5
314	Terrace Clay	5.0+	334	417	1.24	"	C-3
315	"	3.55	622	350	.56	"	"
316	"	1.75	1365	437	.32	"	"
317	"	1.64	1665	433	.26	"	"
318	"	1.49	2783	1966	.71	"	"
319	"	1.37	3192	2100	.66	"	"
320	Terrace Sand	1.46	4057	2236	.55	1000+ or 5	C-2 or C-4
321	"	1.34	4599	2260	.49	1000+ or 10	"
322	"	1.35	5006	2697	.54	1000+ or 4	"
323	"	1.33	5860	2753	.47	1000+ or 11	"
324	"	1.31	6629	1667	.25	1000+	"
325	San Mateo	1.26	8255	2358	.29	"	C-5
330	Terrace Clay	5.0+	374	126	.34	"	C-3
331	"	1.97	697	284	.41	"	"
332	"	1.67	1124	378	.33	"	"
333	"	1.37	1614	479	.30	"	"
334	"	1.32	2313	896	.39	"	"
335	"	1.24	3356	1383	.41	"	"
336	Terrace Sand	1.27	4965	2318	.47	1000+ or 9	C-2 or C-4
337	"	1.24	6287	3200	.51	1000+ or 4	"
338	"	1.24	7039	1504	.21	1000+	"
339	San Mateo	1.21	8701	2592	.30	"	C-5

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TABLE E-1 (Cont'd)

Element No.	Material Type	K_c'	σ_o (psf)	τ_{max} (psf)	$\frac{\tau_{cy}}{\sigma_{fc}}$ $(=\frac{\tau_{max}}{\sigma_o})$	N @ $\frac{\tau_{cy}}{\sigma_{fc}}$ (stress cycles)	Reference Fig. No. for Soil Strength
344	Terrace Clay	3.12	481	113	.24	1000+	C-3
345	"	4.26	388	194	.50	"	"
346	"	1.16	1258	291	.23	"	"
347	"	1.17	1576	411	.26	"	"
348	"	1.15	2558	679	.27	"	"
349	"	1.14	3839	1220	.32	"	"
350	Terrace Sand	1.17	5467	2370	.43	1000+ or 15	C-2 or C-4
351	"	1.17	6733	2788	.41	1000+ or 35	"
352	"	1.18	7385	2630	.36	1000+ or 150	"
358	Terrace Clay	1.74	547	179	.33	1000+	C-3
359	"	2.33	780	508	.65	"	"
360	"	1.06	1694	392	.23	"	"
361	"	1.06	2576	1119	.43	"	"
362	"	1.08	3965	1661	.42	"	"
363	Terrace Sand	1.10	5542	2129	.38	1000+ or 50	C-2 or C-4
371	Terrace Clay	1.58	665	1096	1.65	0.5	C-3
372	"	1.48	840	989	1.18	60	"
373	"	1.08	1736	1512	.87	250	"

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Table E-2

Significant Cycle Analysis

Songs Switchyard Slope Analysis
Element 77
σ_{fc} = 1592 psf
K'_c = 1.0
San Mateo SAND (Strength data in Appendix C, Fig. C-5)

NOTES	DATA FROM COMPUTED TIME HISTORY OF SHEAR STRESS			DATA FROM SOIL STRENGTH CURVE (FIELD)					
	INDUCED CYCLIC SHEAR STRENGTH		NO. OF CYCLES WITH PEAKS IN THIS LEVEL	n_f	Δn_{eq}				
	τ_x (psf)	$\frac{\tau_x}{\sigma_{fc}}$							
τ_{max} τ_{ave} = .65 τ_{max}	2093 1360	1.31 0.85		n_{ref}=1½					
STRESS LEVEL									
1	1840	1.15	2½	½		7.5			
2	1460	0.92	3	1½		3			
3	1170	0.74	17	2½		10.2			
4	635	0.40	17½	85		0.3			
5	500	0.31	15½	—					

For 22 sec. motion, n_{eq} = 21 @ 65% τ_{max}

(for 80 sec. motion, there were 77 cycles @ .65τ_{max})

$$\frac{80 \text{ sec.}}{22 \text{ sec.}} \cong \frac{77 \text{ cycles}}{21 \text{ cycles}}$$

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TABLE E-3

SUMMARY OF FINAL STABILITY EVALUATION DATA FOR ELEMENTS WITH INSTABILITY INDICATED AT STRESS LEVEL τ_{max} (FROM TABLE E-1)

Element No.	Material	$\frac{(0.65)\ \tau_{max}}{\sigma_{fc}}$	K_c'	N	Reference Fig. No. for Soil Strength
112	San Mateo	.67	4.53	105	C-5
140	"	.71	2.08	92	"
184	Weak Lens	.34	1.69	1000+	C-4
197	"	.48	1.83	400+	"
198	"	.49	1.62	40	"
211	"	.32	1.49	1000+	"
212	"	.30	1.36	1000+	"
213	"	.52	1.42	7	"
213	Terrace Sand	.52	1.42	1000+	C-2
224	Weak Lens	.42	1.08	15	C-4
225	"	.42	1.17	17	"
226	"	.44	1.25	20	"
227	"	.62	1.27	2	"
227	Terrace Sand	.62	1.27	300	C-2
237	Weak Lens	.38	1.11	60	C-4
240	"	.39	1.09	60	"
241	"	.65	1.03	1	"
241	Terrace Sand	.65	1.03	20	C-2
242	"	.51	1.00	100	"
242	Weak Lens	.51	1.00	2½	C-4
252	"	.65	1.31	1½	"
252	Terrace Sand	.65	1.31	350	C-2
253	"	.65	1.15	60	"
253	Weak Lens	.65	1.15	1½	C-4
254	"	.62	1.05	1½	"
254	Terrace Sand	.62	1.05	40	C-2
255	Weak Lens	.33	1.03	150	C-4
257	San Mateo	.35	1.17	400	C-5
261	Terrace Sand	.81	1.23	18	C-2
261	Weak Lens	.81	1.23	1	C-4
262	"	.65	1.33	1½	"
262	Terrace Sand	.65	1.33	400	C-2
263	Weak Lens	.31	1.31	1000+	C-4
264	"	.62	1.14	1½	"
264	Terrace Sand	.62	1.14	90	C-2
265	Weak Lens	.49	1.28	8	C-4
266	Terrace Sand	.68	1.29	150	C-2
266	Weak Lens	.68	1.29	1½	C-4
267	"	.54	1.28	3½	"
267	Terrace Sand	.54	1.28	1000+	C-2

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TABLE E-3 (Cont'd)

Element No.	Material	$\frac{(0.65)\ \tau_{max}}{\sigma_{fc}}$	K_c'	N	Reference Fig. No. for Soil Strength
268	Weak Lens	.36	1.28	250	C-4
274	Clay	2.42	3.32	½	C-3
275	Weak Lens	.67	2.20	6	C-4
276	"	.45	1.72	110	"
277	"	.50	1.58	20	"
284	Clay	2.90	4.48	½	C-3
285	"	1.25	2.46	1000+	"
287	"	.50	5.26	1000+	"
290	Weak Lens	.48	1.74	100	C-4
291	"	.47	1.74	110	"
292	"	.44	1.66	200	"
293	"	.37	1.54	1000+	"
305	"	.44	1.55	110	"
306	"	.40	1.43	150	"
307	"	.32	1.39	1000+	"
308	"	.30	1.38	1000+	"
320	"	.36	1.46	1000+	"
321	"	.32	1.34	1000+	"
322	"	.35	1.35	1000+	"
323	"	.31	1.33	1000+	"
336	"	.31	1.27	1000+	"
337	"	.33	1.24	1000+	"
350	"	.28	1.17	1000+	"
351	"	.27	1.17	1000+	"
363	"	.25	1.10	1000+	"

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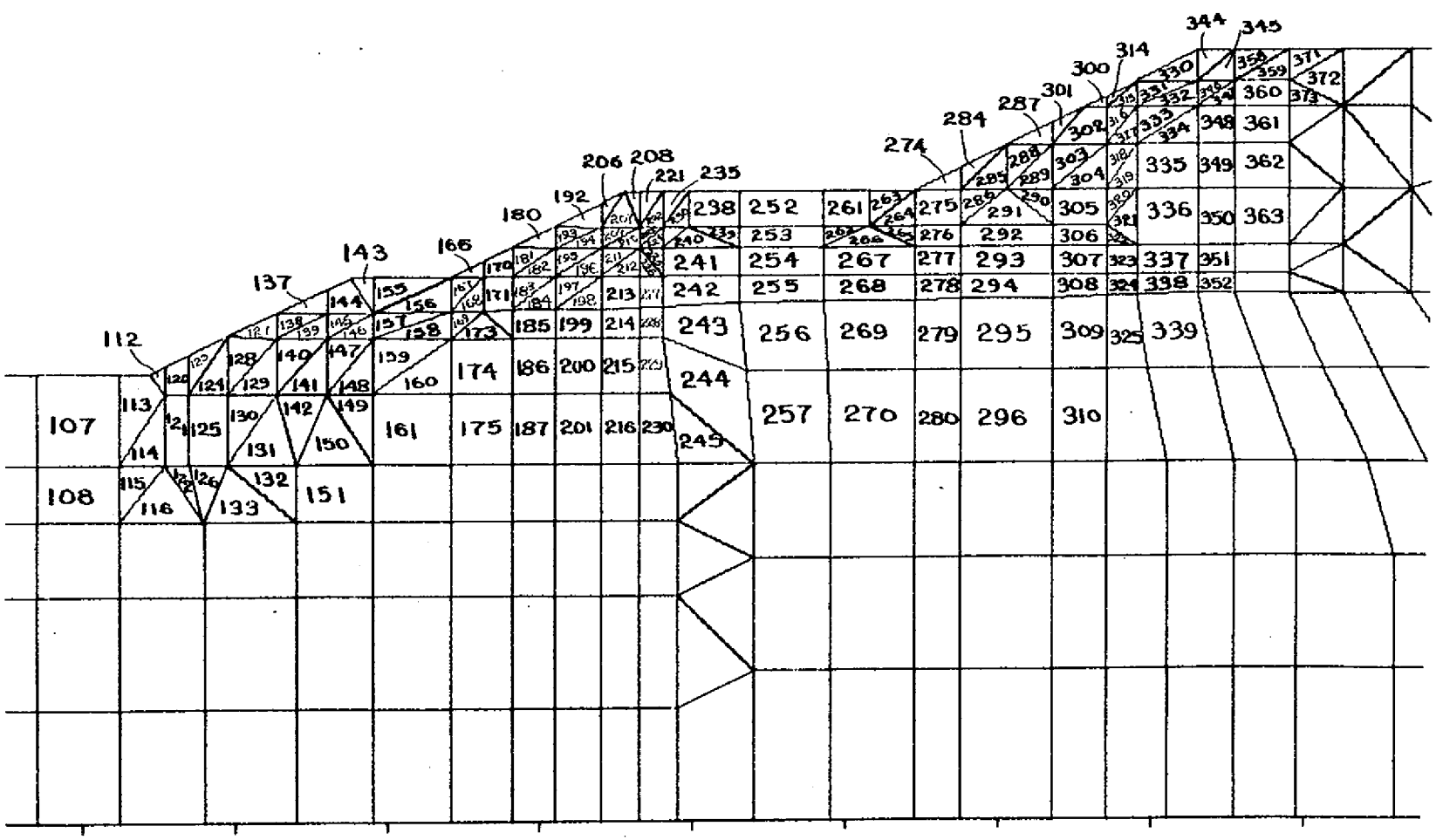
SLOPE PORTION OF FINITE ELEMENT MODEL
Scale 1"=40'
Element Numbers or Given



Project: SONGS SLOPE STABILITY
Job Number: B469A4

FINITE ELEMENT MODEL
WITH ELEMENT NUMBERS

Fig. E-1

2.5E-E15

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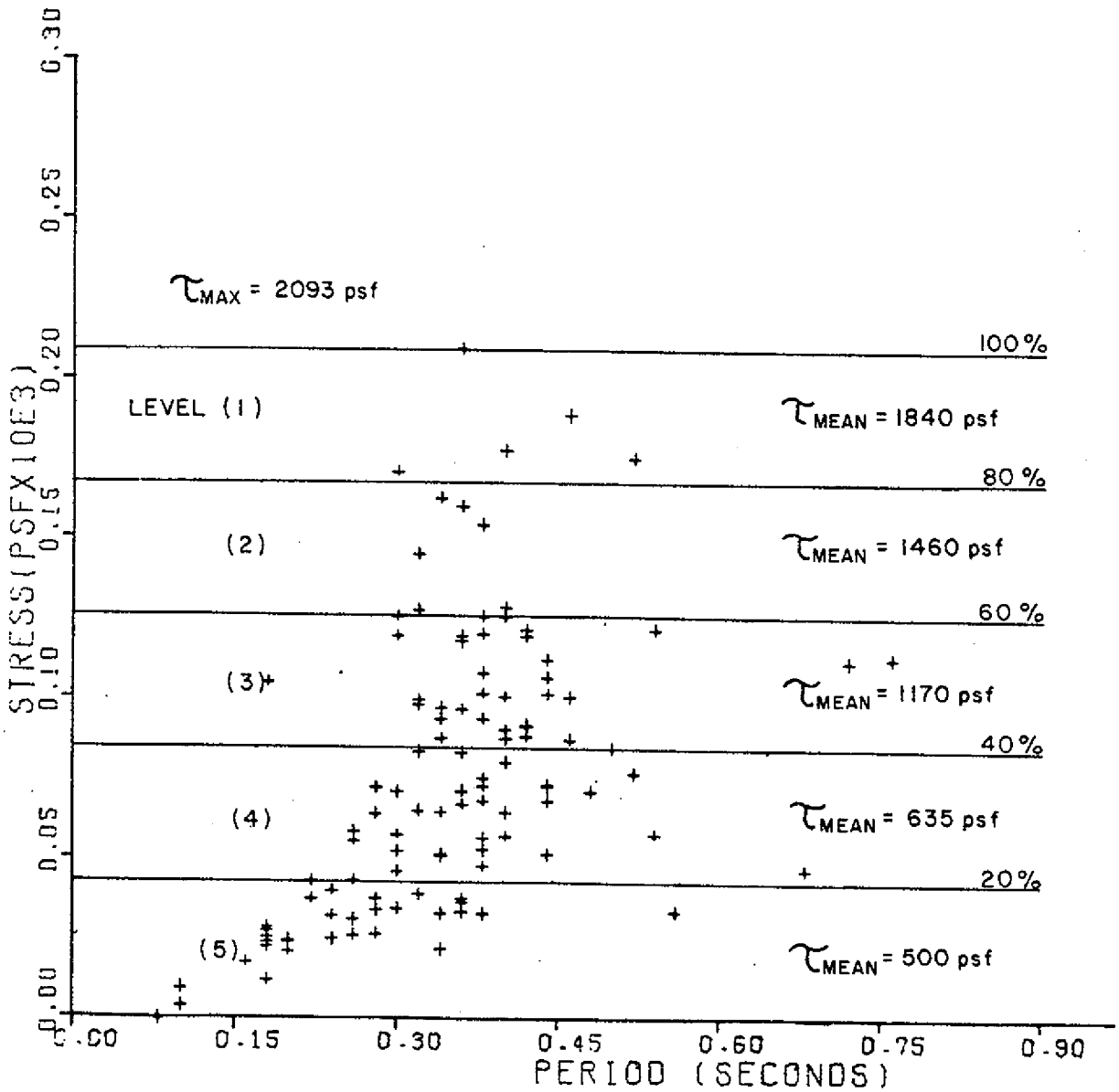

Project: SONGS SLOPE STABILITY **Job Number:** B469A4	PULSE SPECTRUM ELEMENT 77	Fig. E-2

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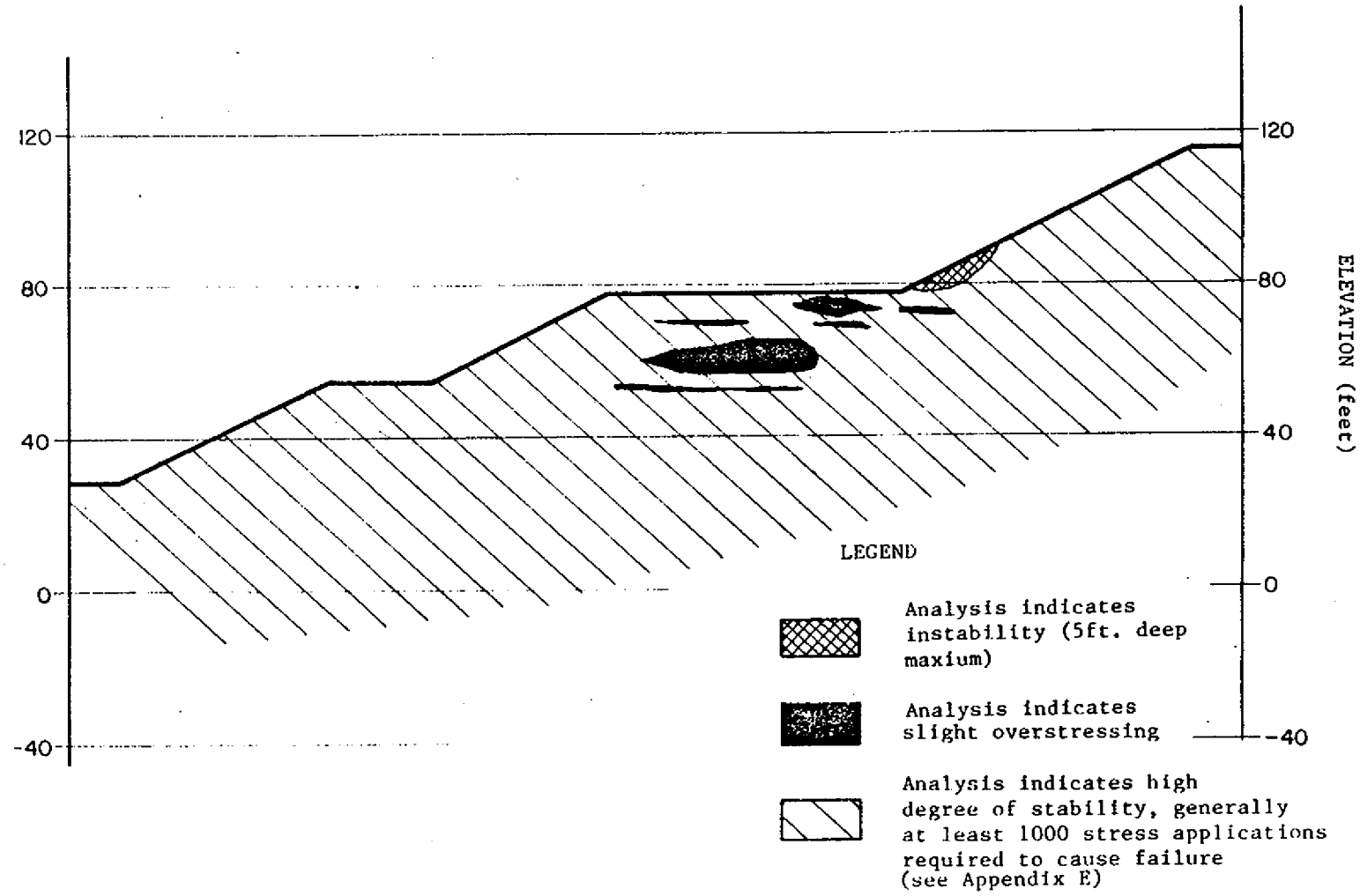
RESULTS OF SWITCHYARD SLOPE STABILITY EVALUATION
(Schematic
Scale 1"=40')



Project: SONGS SLOPE STABILITY
Job Number: 246944

RESULTS OF STABILITY EVALUATION

Fig. E-3

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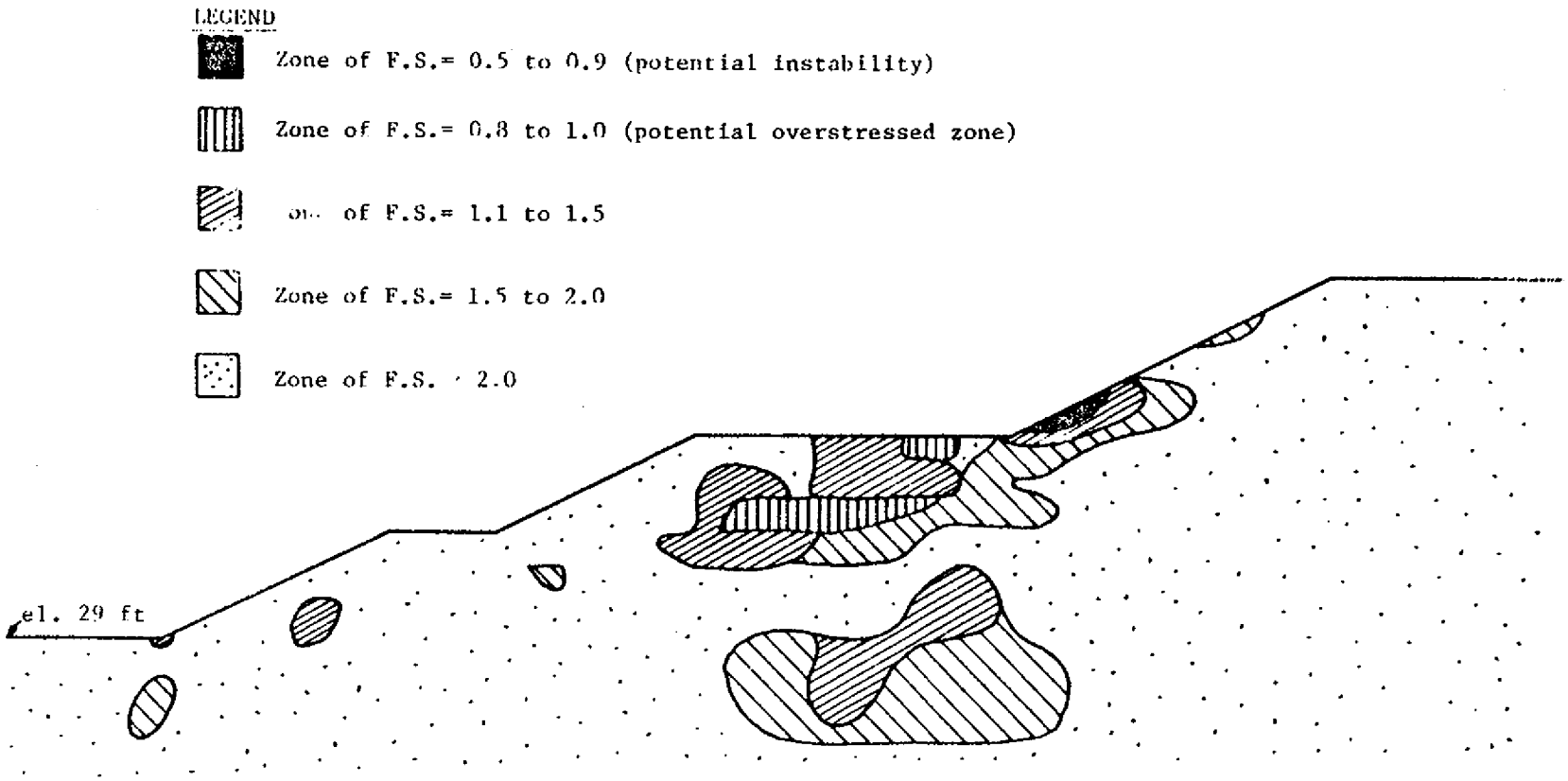

Scale 1" = 40'

(See Fig. 7 for interpreted results)

$$F.S. = \frac{\text{Dynamic Stress at 10\% strain for 80 stress applications}}{\text{65\% of Seismic Induced Stress}}$$

Project: SONGS SLOPE STABILITY

Job Number: B469A4

ZONES OF FACTOR OF SAFETY

Fig. E-4

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APPENDIX F

REFERENCE GUIDE

This appendix presents a reference guide to aid the reader in locating specific items referenced on pages 1.8 - 2bn and 1.8 - 2bo of Amendment No. 19 to the PSAR. This data is presented below, in the order referenced therein.

Item	Where to Look in this Report
1) Drilling	Appendix A
2) Sampling	Appendix A
3) Evaluation of possible disturbance during sampling	Appendix B Section B-2
4) Density, moisture content, and specific gravity tests	Appendix B Section B-1
5) Classification tests	Appendix B Section B-1
6) Dynamic strength tests	Appendix B Section B-2
7) Static strength tests	Appendix B Section B-1
8) Dynamic strength parameters	Appendix C Section C-3
9) Damping and modulus values	Appendix C Section C-4
10) Evaluation of end effects on dynamic test results	Appendix B Section B-2
11) Evaluation of stability	Appendix E
12) Finite element mesh	Appendix D Section D-1
13) Analysis of two soil distributions	Appendix E Section E-2
14) Adjustment of stiffness and damping for strain compatibility	Appendix D Section D-3

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APPENDIX 2.5F

GEOLOGIC REPORT ON THE AREA ADJACENT TO THE SAN ONOFRE NUCLEAR GENERATING STATION NORTHWESTERN SAN DIEGO COUNTY, CALIFORNIA

Site File Copy

GEOLOGIC REPORT
ON THE AREA ADJACENT TO THE
SAN ONOFRE NUCLEAR GENERATING STATION
NORTHWESTERN SAN DIEGO COUNTY, CALIFORNIA

by

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September 31, 1977

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ILLUSTRATIONS

FIGURE 1. Location Map

2. Forest Beds

3. Fossil Locations

4. Reverse Drag Features

5. Geologic Maps Sheet 1 of 3

6. Geologic Map Sheet 2 of 3

7. Geologic Map Sheet 3 of 3

8. Geologic Sections A-A', D-D', F-F'

9. Geologic Sections E-E', G-G'

10. Columnar Section

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INTRODUCTION

This report, prepared at the request of Southern California Edison Company, is based on the study of a 60 square kilometer area extending from San Mateo Canyon on the northwest to Las Pulgas Canyon on the southeast and from the coast to the east side of the San Onofre Mountains. The San Onofre Nuclear Generating Station is in the northwestern corner of the subject area.

This report is based on:

1. Twenty two days (44 man days) of geologic mapping and field study by Perry Ehlig and his field assistant, Thomas Farley, during the period between July 17 and September 6, 1977;

2. the study of two sets of aerial photographs provided by Southern California Edison Company;

3. the review of published and unpublished reports on the geology of the area including pertinent parts of an earlier report on Units 2 and 3 of the San Onofre Generating Station and a report prepared for Los Angeles Department of Water and Power (1971).

4. discussions with staff geologists and consultants of Southern California Edison Company who are associated with the geologic investigation for Units 2 and 3 of the San Onofre Nuclear Generating Station; and

5. prior knowledge of the regional geology and a review of literature pertaining to it.

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REGIONAL GEOLOGIC AND PHYSIOGRAPHIC SETTING

The area surrounding the San Onofre Nuclear Generating Station is in the southwestern part of the Peninsular Range Province of southern California. The main body of the province consists of ranges with a northwest-trending structural grain. Relief within and between ranges is due largely to differential erosion superimposed on broad regional uplift and warping. Differential uplift by faulting has occurred along branches of the Elsinore and San Jacinto faults and along the eastern margin of the province. (See FSAR Figure 2.5-6)

Basement rocks are exposed over much of the province. They include remnants of a thick sequence of Triassic and Jurassic sedimentary and volcanic rocks interspersed between Cretaceous batholithic rocks of granitic to gabbroic composition. The Mesozoic basement rocks are unconformably overlain by Upper Cretaceous and younger sedimentary strata in coastal areas and in the Los Angeles Basin, a structural depression that occupies the northwestern corner of the Peninsular Range Province.

The basement terrane of the Peninsular Ranges probably terminates at or near the northwest-trending South Coast Offshore Fault Zone which is about 5 miles offshore from San Onofre (see Figure 1). All observed basement rock to the west of the fault zone consists of Catalina Schist and associated rocks. This western basement is

considered to be derived from a Franciscan assemblage of sedimentary and volcanic rocks that were deposited on oceanic crust and subsequently metamorphosed at great depth within a late Mesozoic subduction zone (Platt, 1975).

From the perspective of global tectonics, the Peninsular Range Province became a relatively rigid part of the North American continental plate following emplacement of Cretaceous batholithic rocks. Between the Cretaceous and Early Miocene the province appears to have been stable except for gentle westward tilting accompanied by erosion on the east and sedimentation on the west. During this time, interaction between the Farallon and North American plates was taking place to the west.

Reconstructions by Atwater and Molnar (1973) indicate the east Pacific Rise passed beneath the continental margin in the area of the Peninsular Ranges during Early to Mid-Miocene. This corresponds to a period of volcanism and great tectonic activity in the Los Angeles Basin and adjoining California Continental Borderland although little appears to have happened within the interior of the Peninsular Range Province.

Plate reconstructions in combination with data from land based geology suggest large magnitude right slip occurred along northwest-trending transform faults within the Continental Borderland during the Miocene. Commencing about 4.5 million years ago during Early Pliocene and continuing to the present, motion between the Pacific and North American plates has taken place primarily by spreading

in the Gulf of California and right slip along the San Andreas fault and its branches (Atwater and Molnar, 1973). As a result of this, Baja California and the Peninsular Ranges have been detached from the North American plate and become part of the Pacific plate.

During the Pleistocene and Holocene the Peninsular Ranges have been uplifted and warped, probably as a result of interaction between the Pacific and North American plates. Much of the Quaternary deformation within the northern part of the Peninsular Ranges appears to be due to interplate compression along the bend in the San Andreas fault which extends from the northern end of the Salton Trough to the southern end of the Coast Ranges.

LOCAL GEOLOGIC AND PHYSIOGRAPHIC SETTING

Within the coastal area adjacent to the San Onofre Nuclear Generating Station there is a pronounced change in the bedrock geology across the north-northwest-trending Cristianitos fault. The area east of the fault belongs to a large, essentially intact structural block which extends from the Elsinore fault to the coast and includes the Santa Ana, Elsinore, Santa Margarita and San Marcos Mountains along with ranges further to the southeast (see Figure 1). The area west of the fault is part of the Capistrano Embayment, a northward-trending structural trough of Late Miocene and Early Pliocene age which interconnects with the Los Angeles Basin.

The structural block east of the Cristianitos fault has basement rock exposed over most of its surface. About 6 miles inland from the coast the basement terrane is unconformably overlain by a thick

sequence of sedimentary rocks which dip southwestward toward the coast. The lower part of the sequence is Upper Cretaceous to Eocene in age and consists mainly of quartzofeldspathic sandstone derived from erosion of basement terrane to the northeast. Only the upper part of the Eocene La Jolla Group was observed during this investigation. Two to four miles inland from the coast, Eocene strata are overlapped by the Lower to Early Middle Miocene San Onofre Breccia.

The breccia has an average dip of about 35 degrees toward the southwest and a maximum exposed thickness of nearly 4600 feet. It consists of coarse schist debris which was deposited on alluvial fans emanating from a mountainous area southwest of the present coast. Because of its resistance to weathering and erosion, the breccia forms the San Onofre Mountains, a prominant northwest-trending ridge extending from Oceanside to San Clemente along the landward side of the coastal terrace. The Middle to Early Upper Miocene marine Monterey Formation unconformably overlies the San Onofre breccia and generally dips toward the southwest at low to moderate angles. It was deposited by a sea transgressing from the southwest (the direction from which the San Onofre breccia was derived) and includes a basalt conglomerate and sandstone member derived from erosion of the breccia. The bulk of the Monterey Formation consists of thin bedded siltstone, shale and sandstone in the northern part of the area and massive sandstone in the southern part. The Monterey Formation is the youngest bedrock formation present in the study area to the east of the Cristianitos fault.

To the west of the Cristianitos fault is the Capistrano Embayment, a relatively flat-bottomed structural trough trending about north 10 degrees west. The trough was a marine embayment during the Late Miocene and Pliocene but has subsequently been uplifted relative to sea level and is marked by hilly terrain. It is about 3.5 miles wide near the coast and gradually narrows toward the north. The San Onofre breccia and the Monterey Formation are exposed near its margins. Siltstone and sandstone of the Upper Miocene to Lower Pliocene marine Capistrano Formation constitute exposed bedrock within the interior of the trough. The Capistrano Formation has been gently folded in an irregular pattern. The formation is locally capped by subhorizontal siltstone and sandstone of the Upper Pliocene marine Niguel Formation. Sandstone of the Upper Miocene to Lower Pliocene San Mateo Formation crops out adjacent to the Cristianitos fault near the coast and underlies the San Onofre Nuclear Generating Station.

Pleistocene marine terraces are well developed along this part of the southern California coast. The lowest terrace has an average width of about one half mile and is continuous except where interrupted by major drainage courses. It is mantled by marine and non-marine deposits. Numerous higher terraces are present on the southwest flank of the San Onofre Mountains. The highest terrace mantled by beach gravel is at 1,275 feet above sea level. Higher benches of probable marine origin but lacking marine deposits occur as high as 1,500 feet above sea level. The highest terraces may be Pliocene in age. River terraces are present in inland areas but were not encountered during this study except locally adjacent to Las Pulgas, San Onofre and San Mateo Canyons.

The Cristianitos fault is the only major fault in the area. It has an average strike of north 18 degrees west and dips steeply toward the west. Normal dip-slip displacement occurred along the Cristianitos fault in association with development and deepening of the Capistrano Embayment during the Late Miocene and Early Pliocene. The fault has not moved since formation of the lowest marine terrace and has probably been inactive since the Pliocene.

Minor faults are present in many places within the San Onofre breccia but are not generally traceable beyond individual outcrops. Four faults have been mapped because they displace the unconformity between the Monterey Formation and the San Onofre breccia. All four are subparallel to the Cristianitos fault but three have a reverse sense of displacement opposite to that of the Cristianitos. None appear to have been active during the Late Pleistocene or Holocene.

STRATIGRAPHY

DESCRIPTION AND ORIGIN OF FORMATIONS

La Jolla Group

Medium to thick bedded friable sandstone composed of quartz, feldspar and biotite underlies the San Onofre breccia along the north flank of the San Onofre Mountains. In most places the sandstone is covered by soil or slope debris. During our limited examination of the sandstone we found no fossils. Since it has previously been mapped as part of the Eocene La Jolla Group (Moyle, 1973), we have designated it as such on the geologic map (Figures 5, 6 and 7).

Sandstone similar to that described above underlies the San Onofre breccia on the ridge between San Onofre and San Mateo Creeks. We designate it as Eocene La Jolla Group on the geologic map although part of it was previously mapped as the Monterey Formation (Moyle, 1973). It is clearly not part of the Monterey Formation as used in this report and it may belong to the Lower Miocene Topanga or Vaqueros Formations. These units were not differentiated from the underlying La Jolla Group during this study.

San Onofre Breccia

The San Onofre breccia of this area has previously been described by Woodford (1925) and Stuart (1975). Most of the formation is a repetitious sequence of coarse, poorly sorted and irregularly bedded breccia containing sedimentary structures typical of alluvial fan deposits. Clasts within the breccia are angular to

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subangular and are exclusively of metamorphic rock types characteristic of the Catalina Schist and other basement rocks associated with it. Common clast types include: blue-gray glaucophane schist varying from very fine grained schist to schist with abundant epidote crystals as much as 1.5 inches long; gray-green schist composed of variable amounts of chlorite, actinolite, epidote and albite; dark gray muscovite-albite schist; quartz schist derived from chert and containing such minerals as riebeckite, muscovite, manganiferous garnet and piedmontite; milky-white vein quartz; dark colored amphibolite and garnet amphibolite; metagabbro and metaserpentinite. Most clasts fall within the size from granules to small boulders but clasts 3 to 6 feet long are present in many places and the largest observed clast is 43 feet long.

The coarseness of the San Onofre breccia increases from south to north along the San Onofre Mountains and from the base upward within the lower part of the formation. Relatively fine grained sediments representing distal fan deposits are common near the base of the formation throughout the area. Between Horno and Las Pulgas Canyons they comprise the lower 330 feet of the formation and consist of interbedded granule to pebble breccia, sandstone and sandy mudstone varying from light brown to reddish brown in color. Bedding planes tend to be parallel to each other and are commonly well developed in sandstone. Sandy mudstone beds representing old soil horizons are internally massive and grade from brown near the base to red-brown at the top.

The middle and upper parts of the formation appear to represent rapid accumulation on a relatively steeply sloping alluvial fan.

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The most abundant lithology is breccia with clasts ranging from pebbles to small boulders in size and showing clast to clast support. Tabular schist clasts within the breccia tend to have their broad surfaces in subparallel alignment. Clast imbrication is common and characteristically indicates sediment transport from the southwest to the northeast. The matrix between clasts consists of granule- to silt-sized particles derived from mechanical abrasion of the clasts. The fine grained part of the matrix is rich in chlorite and muscovite. Interspersed between breccia beds are thin discontinuous beds of sandstone. The sandstone has the same composition as the matrix of the breccia. Bedding varies considerably in orientation from place to place within individual sandstone beds as well as from one sandstone bed to the next. When seen in fresh exposures, the material forming the sandstone and the matrix of the breccia is greenish gray in color and appears to have experienced little weathering prior to deposition. The red coloration seen in many places along the south flank of the San Onofre Mountains is a surficial weathering feature caused by prolonged exposure during the Quaternary.

Coarse, internally massive beds of probable mudflow origin are fairly common within the middle and upper parts of the formation. Clasts generally show little preferred orientation and are enclosed within a greenish gray, muddy matrix having essentially the same composition as the clasts.

In several places there are thick massive units interpreted to be avalanche deposits. The individual units are typically monolith-

ologic and consist of tightly packed angular fragments of highly variable size.

Tuff beds and tuffaceous sediments occur in a few places. Most are composed of fine grained ash and alteration products derived from ash. The only tuff bed which was traced more than a hundred feet occurs in the highest exposed part of the formation directly northeast of the landward edge of the lowest marine terrace between map grid locations 20,500 feet southeast and 33,800 feet southeast. The tuff is exposed at 9 locations distributed over a distance of 2.5 miles as shown on the geologic map. The main part of the tuff consists of fairly well sorted, closely packed, cream-colored pumice lapilli. The most southeasterly exposure is estimated to be about 16 feet thick, lacks visible bedding and contains angular fragments as much as 2.5 inches long of a dense black volcanic rock scattered among the pumice lapilli. It is interpreted to be an airfall deposit at this location and is probably quite close to the vent. In the northwestern exposures part of the tuff was transported by water as shown by bedding.

The tuff is important because all 9 exposures are in linear alignment parallel to the strike of bedding in the San Onofre breccia. This indicates a lack of significant cross-cutting faults within the 2.5 miles interval in which the exposures occur.

The San Onofre breccia has a maximum exposed thickness of about 4900 feet as shown by cross sections E-E' (Figure 9 of this report). The thickness shown may vary by several percent because of uncertainty concerning the mean dip of bedding and because of pos-

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sible repetition of strata by minor faults. The exposed thickness is greatest in the vicinity of San Onofre Mountain and this southward due to original lensing in this direction and thins northward due to unconformable overlapping by the Monterey Formation. The entire thickness is of nonmarine alluvial fan origin. Stuart (1975) refers to the presence of marine fossils within the San Onofre breccia of this area; however, the strata which contain marine fossils are assigned to the Monterey Formation in this study.

The San Onofre breccia is of Late Lower to Early Middle Miocene age as shown by its stratigraphic position. The age of the strata immediately underlying it is not known within this area.

The lower part of the Monterey Formation which unconformably overlies the San Onofre breccia in this area contains abundant fossils of Middle Miocene age.

The San Onofre breccia is a product of tectonic activity within the nearshore part of the Continental Borderland. It was derived from a landmass southwest of the present coast as shown by paleocurrent directions derived from clast imbrication and by the fact that clast types are characteristic of Catalina Schist terrane which is only known to occur to the west of the present coast. (see Stuart, 1975, for greater detail). The coarseness and thickness of the breccia is characteristic of accumulation along a fault scarp adjoining a subsiding basin. The source area must maintain high relief in order to deliver coarse debris while at the same time the crust beneath the alluvial fan must be subsiding in order to allow thick deposits to accumulate. It should be noted that although the San Onofre

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breccia has been referred to as an alluvial fan deposit, it actually represents a coalescence of fans derived from several drainage systems emanating from a relatively linear range front. This is shown by the fact that the types of clasts present and their relative abundances vary along the trend of the range and by the fact that paleocurrect directions are subparallel along the trend of the range rather than being arranged in a fan shape. Deposits interpreted to be of avalanche origin and some of the very coarse debris, including a block 43 by 27 by 19 feet and another 38 by 27 by 13 feet, may have originated by landsliding from a steep mountain front or escarpment.

Monterey Formation

In the coastal area southeast of the Cristianitos fault the non-marine San Onofre breccia is unconformably overlain by marine strata which vary in their gross lithology both laterally, parallel to the trend of bedding, as well as stratigraphically upward perpendicular to bedding. This has led to uncertainty concerning the assignment of formation names and has resulted in conflicting assignments among prior geologic reports on the area. The problem has been resolved by the dating of microfossil assemblages from 14 widely scattered localities within the area between the Cristianitos fault and Las Pulgas Canyon (Figure 3). All of the microfossil assemblages are of Middle to Early Upper Miocene age (Table 1). Marine strata of this age are traditionally assigned to the Monterey Formation in coastal areas of California and are so assigned in this report. (Anderson, Warren, 1977, Appendix A)

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In the area of the Capistrano Embayment to the west of the Cristianitos fault, Woodford (1925, p. 216-217) established the Capistrano Formation to include Upper Miocene and Lower Pliocene marine shale and sandstone which conformably overlie shale of the Monterey Formation but are lithologically different from it. Although the two formations are different in their gross appearance, they contain overlapping lithologies such as diatomaceous shale. This causes uncertainty concerning placement of the contact between the two formations. Our formational assignments are consistent with those of Blanc and Cleveland (1968) who have mapped the contact in the area north of San Clemente. It should be recognized that the Capistrano Formation is a local name. Had it not been established, the Upper Miocene strata included within it would either be referred to as part of the Monterey Formation or the Puente Formation, a local formational name used to the northwest of this area.

The base of the Monterey Formation is exposed in several places near the northwest end of the San Onofre Mountains. The base is concealed beneath deposits mantling the lowest marine terrace in most of the area southeast of the Cristianitos fault and lies at depth beneath the Monterey and younger formations in the area west of the Cristianitos fault.

The basal part of the formation consists of conglomerate and coarse grained sandstone derived from erosion of the San Onofre Breccia. These basal deposits are as much as 160 feet thick in the area upslope from the lowest marine terrace between map grid locations 6,000 and 12,000 feet southeast. A series of small sand and gravel borrow pits have been excavated in the basal member adjacent to the

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old highway in this area and provide good exposures. The basal member can be distinguished from the underlying San Onofre breccia by (1) better sorting of clasts and an absence of clasts larger than cobbles, (2) the presence of better rounded clasts, (3) the absence of silt and clay from the matrix of the sandstone and conglomerate, (4) the local occurrence of shells, particularly oyster and pectin shells, and (5) the presence of light colored calcareous material filling the spaces between clasts in some beds. The basal member was previously mapped as part of the San Onofre breccia by Woodford (1925) and Stuart (1975). However, the two formations are separated by an angular unconformity and represent very different depositional environments. The San Onofre breccia was deposited by an alluvial fan emanating from the southwest whereas the Monterey Formation was deposited by a sea encroaching from the southwest.

In the area described above there is a buttress unconformity between the Monterey Formation and the San Onofre breccia as illustrated in Figure 2. The relationships are best seen in the vicinity of a flat-topped ridge near map grid location 9000 feet southeast, 4,500 feet northeast. Bedding within the San Onofre breccia has an average dip of about 37 degrees to the southwest in this area. The unconformity dips about 30 degrees to the southwest as shown by its outcrop pattern. A resistant calcareous conglomerate unit, 10 feet thick, underlies and structurally controls the crest of the flat-topped ridge. The conglomerate unit dips 12 degrees toward the southwest and converges with the unconformity at its uphill end. The conglomerate unit is made up of a series of foreset beds which

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dip about 40 degrees toward the southwest and represent a seaward prograding of beach derived material, perhaps following deep scour by a severe storm. A good view of these relationships can be obtained by taking the powerline road to the crest of the ridge southeast of the site. Similar relationships are present elsewhere in this general area. The buttress unconformity may represent deposition of sediment against a submerged and erosionally flattened wave cut cliff.

To the north-northwest of the above location, the thickness of the basal sandstone and conglomerate member decreases and bedding within it becomes subparallel to the underlying unconformity. Both dip gently toward the southwest at an angle of about 25 degrees less than the dip of the underlying San Onofre breccia. This probably reflects transgression of the Monterey sea across a subhorizontal erosion surface cut across breccia dipping 25 degrees to the southwest.

On the ridge between San Onofre and San Mateo Canyons, the base of the Monterey Formation overlaps the base of the San Onofre breccia and rests upon the underlying Eocene sandstone. In part of this area the basal sandstone and conglomerate member is no more than 3 feet thick. Diatomaceous and calcareous shale are directly above the unconformity.

From the Cristianitos fault southeastward to Las Pulgas Canyon, the Monterey Formation is well exposed in the lower part of the sea cliffs and in the mouths of canyons in areas not affected by landslides. The exposed beds occupy a relatively thin stratigraphic interval which is probably 100 to 150 feet above the base of the

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Monterey Formation in most places (see cross sections CC', DD' and EE' Figures 8 & 9). The lithology of the Monterey Formation undergoes lateral facies changes along this segment of the coast. Close to the Cristianitos fault the exposed strata consist of dark brown to greenish gray thin bedded siltstone and clayey siltstone with thin tuff beds scattered through the section, near grid location 13,500 southeast exposed strata consist of interbedded clayey siltstone and fine grained arkosic sandstone rich in biotite. Southeast of grid location 18,000 feet southeast the exposed strata consist mainly of coarse grained arkosic sandstone. From grid location 28,000 feet southeast to Las Pulgas Canyon the exposed strata are almost entirely massive coarse grained arkosic sandstone. This change in lithology is due to lateral changes in the depositional environment. The massive sandstone along the southeastern part was probably deposited by grain flow near the head of a submarine fan. Thin bedding siltstone near the Cristianitos fault probably represents pelagic sediments deposited on a flat-bottomed ocean floor. Strata exposed in between the two areas probably represent the zone of interfingering between fan derived sediment and pelagic sediments.

South of the area shown on the Geologic Map, the arkosic sandstone is exposed along the coast near Las Pulgas Canyon may have been transported down a submarine channel which had approximately the same location as Las Pulgas Canyon. The Monterey Formation exposed on the west side of Las Pulgas Canyon at fossil locality 27B-1 (see Table I) (map grid SE38420 ft., NE 11360 ft.) consists of very thin beds of fine grained biotite-rich arkosic sandstone

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separated by diatomite partings. One of the beds contains a mat of fish fossils. This sequence of strata which has an exposed thickness of about 16 feet is truncated on the southeast by massive coarse grained arkosic sandstone. The contact between the two is steeply inclined but irregular and clearly of sedimentary origin.

Only massive arkosic sandstone is exposed across the entire hillside to the southeast. Based on the above relationships, the sandstone appears to be backfill within a submarine channel.

The upper part of the Monterey Formation is exposed to the west of the Cristianitos fault between San Onofre and San Mateo Canyons. It consists of thin bedded diatomaceous siltstone and clayey siltstone with thin ash beds present at fossil locality 57B-2.

Fossil localities are shown on Figure 3 and data pertaining to them are summarized in Table 1. Microfossil assemblages were analyzed by Anderson, Warren and Associates, Inc., (1977, Appendix A) from 14 localities within the Monterey Formation to the east of the Cristianitos Fault and from 4 localities in the Monterey Formation and 2 localities within the lower part of the Capistrano Formation to the west of the Cristianitos fault.

The microfossil data indicate most of the Monterey Formation east of the Cristianitos fault belongs to the Luisian Stage of the Middle Miocene. This is equivalent to an absolute age of 14 $\pm$ 1 million years according to correlation charts currently in use. (Anderson, Warren and Assoc., 1977, Appendix A.) Microfossils from 3 localities east of the fault belong to the Lower Mohnian Stage of the Early Upper Miocene. This equates to 13 $\pm$ 1 million

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years according to Anderson, Warren and Assoc., (1977, Appendix A). An additional locality east of the fault gives a less diagnostic age of probable Upper Miocene.

Of the four microfossil localities in the Monterey Formation to the west of the Cristianitos fault three indicate a Late Miocene age and one indicates a Middle Miocene age. The strata at locality 49A-1, which yields a Middle Miocene age, are strongly deformed and have probably been dragged upward along the Cristianitos fault. Microfossils from locality 49C-1 belong to the Upper Mohnian Stage of the Upper Miocene and are equivalent to an absolute age of between 9 and 12 million years. This locality is several feet below the base of the San Mateo Formation and represents the youngest part of the Monterey Formation in this area.

The Monterey Formation was deposited during a period of relatively rapid subsidence (or rise in sea level). Part of the basal sandstone and conglomerate were deposited within the surf zone and contain shallow water oyster and pectin shells. Yet the diagnostic microfossil assemblages indicate bathyal depths of 600 to 1200 feet. Localities 49C-2 and 58A-1 are within a few feet of the base of the Monterey Formation yet both indicate middle bathyal depths during the Luisian Stage. As a result of the relatively rapid increase in water depth, the near shore topography was probably fairly rugged during deposition of the lower part of the Monterey. This is probably the reason for the relatively abrupt lateral and vertical changes in the lithology of the Monterey Formation in this area.

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Capistrano Formation

The Capistrano Formation occurs within the Capistrano Embayment where it overlies the Monterey Formation with apparent conformity. Only a few exposures of this formation were observed along the west side of San Mateo Canyon during the present investigation. The exposed strata consist of interbedded siltstone, mudstone and fine grained biotite-rich arkosic sandstone. Diatomaceous siltstone occurs with the above lithologies at fossil localities 57D-1 and 57D-2, to the north of the Geologic Map area.

The transition between the Capistrano Formation and underlying Monterey Formation is exposed in section 27 (T.8S.R.7W.) directly northwest of the study area. Here, the upper part of the Monterey Formation consists of thinly interbedded diatomaceous siltstone and clayey siltstone. The basal part of the overlying Capistrano Formation consists of interbedded mudstone, clayey siltstone and fine grained biotite-rich sandstone. This grades upward into a more thickly bedded sequence dominated by fine to medium grained sandstone rich in biotite.

The Capistrano Formation is of Late Miocene and Early Pliocene age as determined from foraminifera by White (1956). Localities 57D-1 and 57D-2 on the west side of San Mateo Creek yielded microfossils indicating a probable Late Miocene age. The study by White (1956) indicates much of the Capistrano Formation was deposited at bathyal depths of 600 to 12,000 feet.

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San Mateo Formation

The San Mateo Formation forms the bedrock beneath the San Onofre Nuclear Generating Station and is well exposed in the sea cliffs adjacent to the station. Strata specifically designated as belonging to the San Mateo Formation crop out in a relatively small triangular area bounded by the Cristianitos fault on the east, by the coast on the southwest and, on the north, by a line trending south 70 degrees west from where the Cristianitos fault crosses San Mateo Creek.

Within the area covered by the geologic map, the San Mateo Formation is primarily composed of massive, coarse grained, light yellow-brown to light gray arkosic sandstone. Discernible bedding is rare in most exposures. Lenses of pebble-cobble conglomerate occur in a few places. Clasts within the conglomerate are rounded and include volcanic and granitic rocks along with rocks reworked from the San Onofre breccia. The upper part of the formation contains broad open cross beds in exposures north of Basilone Road about 1/2 mile east of the Camp Pendleton entrance.

The San Mateo Formation is only slightly deformed except in areas close to the Cristianitos fault. In areas where bedding is present, it commonly varies in orientation due to initial deposition on sloping surfaces.

The maximum thickness of the San Mateo Formation within its outcrop area is estimated to be less than 1000 feet. The formation extends from the surface to a depth of 900 feet beneath San Onofre Nuclear Generating Station (FSAR Section 2.5.4.2.1.3). Since bedding is

gently inclined the vertical thickness should be close to the true stratigraphic thickness in this area.

The San Mateo Formation appears to be entirely of marine origin. The massive coarse grained sandstone comprising the lower part of the formation near the Cristianitos fault was probably transported by grain flow and could have been deposited within a wide range of water depths. Broadly cross bedded sandstone in the upper part of the formation might also have formed in a wide range of depths but by current action. The sand within the formation was probably transported into this area by the ancestral drainage systems to San Onofre and San Mateo Creeks. The formation probably represents the backfilling of a submarine channel which extended from the mouths of the two creeks. Localization of the formation to this area may have been due to the creation of a structural trough along the down thrown side of the Cristianitos fault. Channels might also have been eroded by sediment being transported from the Capistrano Embayment into a deeper open-ocean basin to the southwest.

The San Mateo Formation has not yielded fossils or other material suitable for dating. Stratigraphic relationships bracket its age as between Early Late Miocene and Late Pleistocene. Its age is generally interpreted to be younger than the Capistrano Formation because it overlies the Capistrano Formation in the area west of San Mateo Creek. However, exposures of the San Mateo Formation in the cliffs along San Clemente State Beach have been examined and it is believed they represent turbidite deposition within a submarine channel within the Capistrano Formation. The San Mateo Formation is well bedded in this area, and displays the Bouma (1962)

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sequences of turbidite structures. Very similar deposits occur as channel backfills within the Capistrano Formation near Dana Point and are described by Bartow (1966) and Piper and Normark (1971). Therefore, the San Mateo Formation is probably a facies of the Capistrano Formation. The lower part of the San Mateo Formation might be Late Miocene in age and could have been deposited synchronous with the lower part of the Capistrano Formation. The upper part of the San Mateo formation is probably Early Pliocene in age where it rests against the Capistrano Formation at San Clemente State Beach.

Marine Terraces and Associated Deposits

The seaward flank of the San Onofre Mountains contains a remarkable number of marine terraces consisting of wave cut benches which are in part mantled by marine and non-marine deposits. The lowest terrace forms the coastal plane and is essentially intact. Terraces above an elevation of about 450 feet are only locally well preserved due to the combined effects of undercutting of higher terraces during formation of lower terraces and subsequent erosion associated with downcutting of canyons. Deposits on terraces above the elevation of 450 feet are limited to beach gravel and fine grained sediments filling in around the gravel. Much of the gravel is concentrated in beach bars which are in linear alignment from one terrace to the next. The highest occurrence of beach gravel is at an elevation of 1275 feet. Remnants of what appear to be wave cut benches extend to an elevation of about 1550 feet. The crest of the mountains is marked by a gently sloping erosion surface which is probably of non-marine origin.

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Marine terraces are not shown as such on the geologic map; only the terrace deposits are shown. Deposits designated as marine in origin consist mainly of pebble-cobble gravel on all but the lower terraces. Beach gravel is easy to distinguish from gravel derived directly from the San Onofre breccia because it is well rounded and is dominantly composed of rock types not found in the San Onofre breccia. The most abundant rocks are volcanic in origin. They probably came from outcrops of the Jurassic Santiago Peak Volcanics in the Santa Margarita Mountains and were transported to the coast by San Mateo, San Onofre and Horno Creeks. Granitic rocks make up a small part of the beach gravel. Their principal source appears to have been Horno Canyon since they are considerablely more abundant to the southeast of it than to the northwest. Beach drift was from northwest to southeast (as it is today) as shown by the symmetry of scallops in the old shorelines. A moderate amount of the beach gravel is derived by reworking of clasts from the San Onofre breccia. Unlike the angular to subangular clasts in the breccia, it is well rounded and, in the case of quartz-rich clasts, typically shows percussion marks from having been tossed in the surf. Beach armor is common at the base of beach gravel deposits and the upper surf zone downslope from the beach. The armor consists of boulders derived from the San Onofre breccia which were too large to be transported by the surf. They show rounding and sculpturing from abrasion by sediment being moved by the surf.

Marine terraces are generally assumed to be Pleistocene in age and to relate to glacially induced changes in sea level. In areas such as this where terraces occur at high elevations, the terraces

are assumed to have been uplifted by tectonic processes. If the above assumptions are applied to the San Onofre area, questions concerning the tectonic stability of the area must be considered. Data collected during this study, indicate the marine terraces in this area represent a gradual recession of sea level since Lower Pliocene and is a feature which affects the entire region, not just the San Onofre Mountains. Evidence for this conclusion are developed below.

The first question is whether the observed terraces are essentially a regressional sequence with the oldest at the top and the youngest at the bottom. With one minor exception, the terraces appear to be a recessional sequence. Terraces undoubtedly formed during eustatic low stands in sea level but were later reworked when the bench was reoccupied by the long-term lowering of sea level. This conclusion is supported by the following three lines of evidence.

First, there should be an overlapping of terrace deposits if higher terraces are younger than lower ones. Only one example of this has been observed and it only involves an increase of about 30 feet in terrace level. This example is exposed in the canyon opposite grid location 29,500 feet southeast. The base of the lower terrace is at elevation 370 feet and the base of the overlapping terrace is at an elevation between 400 and 405 feet. The head of the higher terrace is no more than a few tens of feet further inland than the head of the lower terrace. In the case of the higher terraces, only gravel deposits are present but they are concentrated in bars with a relatively clean wave cut bench downslope from each bar. Had higher terraces formed after lower ones, debris transported down slope during formation of the higher terraces should have

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been deposited over the lower terrace. Even if later erosion removed all fine grained material, a layer of lag gravel should blanket the lower terrace. Such deposits have not been observed.

A second reason for believing the terraces were formed by a long term lowering of sea level is that in many places the higher terraces have been removed by undercutting during formation of lower terraces. The position of the higher terraces is occupied by a faceted ridge representing the remants of a wave cut cliff of a lower terrace. Had the higher terraces formed after lower ones, they should be marked by continuous wave cut benches which truncate the top of the wave cut cliff at the head of the lower terrace.

The third reason relates to the occurrence of volcanic clasts in the terrace gravel. The nearest source for the gravel is the Santa Margarita Mountains, a minimum of 4 miles to the northeast. The area northeast of the San Onofre Mountains is presently occupied by the broad deep valleys of San Mateo, San Onofre and Horno Creeks. These valleys could not have been eroded below the level of the marine terraces at the time the terraces formed. Had they been deeper they would have been unable to deliver the gravel which occurs on the terraces. The above valleys do contain river terraces indicating oscillations in base level but the oscillations are small compared to the total relief within the valley.

The higher terraces on San Onofre Mountain are probably Pliocene in age and probably correspond to a decline in sea level near the close of deposition of the Capistrano Formation. As explained in the discussion of the Cristianitos fault, the Capistrano

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Formation was deposited in 2000 to 4000 feet of water. During its deposition the marine strand line was along the base of an upland erosion surface which extends across the Peninsular Ranges to the north and northeast of this area. A decline in sea level occurred in late Pliocene time. The Upper Pliocene Niguel Formationl which caps the Capistrano Formation at elevations between about 400 and 700 feet above sea level in the Capistrano Embayment, is of shallow marine origin. It reflects a recession in sea level. There is no evidence of younger marine terrace deposits overlying the Niguel Formation in inland areas. Had sea level risen during the Pleistocene to create the terraces on the San Onofre Mountains, there should be a record of this rise in the form of Pleistocene marine deposits in low lying inland areas, such as around El Toro. Pleistocene marine deposits are not known to occur in these areas.

High level marine terraces are known in other areas of southern California. Marine terrace deposits cap the crest of the San Joaquin Hills to the northwest of this area at an elevation of 1000 feet. They occur up to about 1300 feet in the Palos Verdes Hills. The terraces are referred to as Pleistocene but none of the high level terraces have been dated. All of the area surrounding the Los Angeles basin was occupied by deep water during Early Pliocene. The high level terraces may reflect the recession of the Early Pliocene sea.

The marine terraces within the study area show no evidence of major deformation since their formation. Data are inadequate to determine if there has been small scale deformation. In the case of the lowest marine terrace, the elevation of its base varies

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regionally in exposures along the coast. However, this probably reflects the extent to which the wave cut bench has been removed by erosion.

The elevation along the head of the lower 100 to 200 foot present day terrace varies from place to place also but this reflects variation in the thickness of deposits overlying the marine platform.

Elevations are high in areas where minor drainage systems have deposited alluvial fans across the terrace surface. Elevations are low adjacent to major drainage systems, such as Las Pulgas Canyon where channels are adjusted to modern sea level.

GEOLOGIC STRUCTURE

Cristianitos Fault

The Cristianitos fault crosses the coast .9 miles southeast of San Onofre Nuclear Generating Station. Here, it is well exposed in the sea cliff. The fault plane has an average strike of about north 32 degrees east and an average dip of 58 degrees to the southwest. Well developed slickensides trend subparallel to the dip. Sandstone of the San Mateo Formation forms the west wall of the fault and thin bedded siltstone of the Monterey Formation forms the east wall. These relationships indicate the Cristianitos fault is a normal dip-slip fault with the west side down.

At the outcrop of the Cristianitos fault in the bluffs at San Onofre State Beach, terrace deposits overlie bedrock at an elevation of about 55 feet above sea level. About 3 feet of marine gravel occurs at the base of these deposits and is overlain by 39 feet of nonmarine material. The terrace deposits extend directly across the fault without being offset; thus, dating the most recent displacement as older than the terrace deposits. There is no evidence indicating Quaternary offset along the Cristianitos fault within the area studied.

In the sea cliff exposures to the northwest of the Cristianitos fault, beds within the San Mateo Formation are arched into a broad anticline and cut by numerous small faults as illustrated in Figure 4. These features are typical of "reverse drag" along normal fault as described by Hamblin (1965). They probably result from a flattening of the dip of the Cristianitos fault at depth beneath this area.

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The Cristianitos fault is concealed beneath the coastal continental terrace for about one half mile. North of the terrace, the fault trends directly north for .9 miles and then bends westward where it disappears beneath nonmarine terrace deposits. Along this segment of the fault the unconformity between the Monterey Formation and San Onofre Breccia is essentially at ground elevation on the east side of the fault and the San Mateo Formation is on the west side. The San Mateo Formation shows normal drag with bedding dipping more steeply toward the west in beds close to the fault than in those a short distance away. Secondary faults occur subparallel to the main fault within the San Mateo Formation; however, we did not find two separate throughgoing fault traces.

From the east side of San Onofre Canyon to San Mateo Canyon, the Cristianitos fault has an average trend of about north 25 degrees west. The change in trend from that present further south appears to have no special significance. It is common for normal faults to have bends in them as original features, for example, see Hamblin (1965) Figure 1. The dip of the fault in this area is probably steep but exposures suitable for measuring the dip are lacking. The unconformity at the base of the Monterey Formation is within 165 feet of the ground surface on the north side of the fault within most of this area and the contact between the San Mateo Formation and the Monterey Formation is within 165 feet of the ground surface in most areas along the south side of the fault. Thus, the stratigraphic separation along the fault is approximately equal to the stratigraphic thickness of the Monterey Formation, or about 855 feet

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based on the thickness of the Monterey Formation penetrated in an oil well drilled 2.5 miles to the northwest (Humble Oil and Refining Co., Visbeek No. 1.). This offset is somewhat less than would be obtained by projecting stratigraphic horizons into the fault from a short distance away because strata are dragged upward along the west side of the fault.

The gentle east dips in the San Onofre breccia on the north side of San Onofre Canyon are an anomalous feature. They may be due to backward rotation along an arcuate slip surface within soft sandstone beneath the breccia. The mode of failure would be like that of an arcuate landslide except that the toe of the failure plane would terminate at depth against the Cristianitos fault and movement of the block would be associated with fault movement.

Activity along the Cristianitos fault probably occurred primarily during late Miocene and Early Pliocene in association with subsidence in the Capistrano Embayment. The embayment appears to have formed by crustal extension in an east-west direction and its subsidence was accompanied by deposition of the Capistrano Formation. Paleontologic data from surface samples collected a few hundred feet above present sea level indicate water depths increased during accumulation of the Capistrano Formation. Water depths were between 2,000 and 3,000 feet during the Late Miocene and 2,000 to 4,000 feet furing the Early Pliocene (White, 1956). Such water depths would not have been possible without down-dropping the Capistrano Embayment relative to the Peninsular Ranges to the east. Otherwise, the sea would have extended across the top of an old, somewhat deformed, erosion surface that presently lies at an eleva-

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tion between 2,000 and 3,500 feet above sea level within the interior of the mountains. Within the headwaters of San Mateo Creek remnants of a once extensive lava field cap the erosion surface. The lava flows have been dated at 8.3 $\pm$ 0.5 million years (Hawkins, 1970). This age is within the Late Miocene. Since the lava flows were deposited on a land surface, the sea could not have extended to the elevation of the flows.

Fault "E" and Related Faults

Minor faults are fairly common within the San Onofre Breccia. In most places they cannot be traced because of inadequate exposures and repetitious lithology. An exception occurs in the northwestern part of the San Onofre Mountains where remnants of the Monterey Formation overlie the San Onofre Breccia. The contrast between the lithologies of the two formations makes it possible to trace faults which offset the contact between them. Four such faults have been recognized.

The largest of the four, referred to as the fault E on the geologic map, offsets the base of the Monterey Formation about 330 feet vertically with the north side down. The fault is not exposed but can be located within a few feet in areas where it brings the two formations in contact. The fault has been projected across areas where only breccia is present. Along the northwestern part of the fault, as shown on the map, the projection was done to link up known fault segments where the Monterey Formation has been downfaulted against breccia.

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Two faults with displacements similar to the fault E occur to the northeast of the fault E. Neither of the faults is exposed. In both cases a fault has been shown on the map because the basal part of the Monterey Formation has been juxtaposed against breccia.

The fourth fault, referred to as the fault F on the map, (Area 4), has a dip slip separation of about 26 feet with the west side down. The fault surface is well exposed in a small quarry adjacent to the old highway. It strikes about north 15 degrees west and dips about 78 degrees southwest where exposed in the quarry. Striations occur in more than one direction on the fault surface but steeply inclined striations predominate.

None of the above faults shows evidence of Quaternary activity. The only places where there is physiographic expression along these faults is where erosion has worn down the softer Monterey Formation more than the breccia. It should be noted that the fault E and the other two faults which down drop Monterey Formation on their northeast sides must have been active before erosion stripped the Monterey Formation from the main part of the mountainside in this area, otherwise there would have been no Monterey Formation to down drop. The only reason the Monterey Formation is still present is because it was down faulted while the Monterey Formation still covered the breccia and has subsequently been protected by breccia from erosion. Remnants of a marine terrace mantle the San Onofre breccia between elevation 800 and 900 feet along the ridge crest from the center of the fault E. Since this terrace rests on breccia, it postdates removal of the Monterey Formation from the southside of the fault and therefore postdates down faulting of the

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Monterey. On the south end of fault E the remnants of a marine terrace appear to extend across the fault at an elevation of 350 feet. Bulldozing has disturbed the ground surface in this area and leaves doubt concerning whether the terrace is intact.

Faulting within the San Onofre breccia and overlying Monterey Formation might be due to several causes. Much of the minor faulting within the breccia is probably related to folding of the breccia into its present orientation. The breccia lacks well developed bedding planes that can act as flexural slip surfaces during folding. As a result, it acts as a brittle substance and accommodates bending by adjustments along small faults.

The northerly trend of the four faults described above suggests they may be related to the Cristianitos fault or to a system of faults in the San Joaquin Hills to the west of the Capistrano Embayment. The San Joaquin Hills contain numerous north to northwest trending faults which cut Lower and Middle Miocene formations. Many of the faults have Miocene volcanic dikes intruded along them. Thus, at least part of the faults, if not all of them, are Miocene in age.

SUMMARY OF THE GEOLOGIC HISTORY

The coastal area adjacent to the San Onofre Nuclear Generating Station was tectonically very active during the Miocene and Lower Pliocene. Near the beginning of the Middle Miocene, the San Onofre Breccia was deposited on coalescing alluvial fans emanating from an uplifted Catalina Schist terrace located southwest of the present coast. The breccia appears to have accumulated very rapidly within

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a subsiding basin. During the early part of Middle Miocene, the breccia was tilted southwestward and partially eroded. About the same time the sea transgressed from the southwest depositing the Middle Miocene Monterey Formation on the breccia. Submergence appears to have occurred rapidly. The basal part of the Monterey Formation contains beach deposits yet less than 330 feet above the base faunal assemblages indicate middle bathyal depths.

The Capistrano Embayment developed during the Late Miocene and Early Pliocene. Dip slip displacement along the Cristianitos fault allowed the embayment to become a deep marine trough while the Peninsular Ranges to the east remained above sea level.

Since late Pliocene, the area has been uplifted gradually above sea level, but otherwise appears to have been tectonically stable. Topographic features in the area are products of differential erosion rather than tectonic activity. The San Onofre Mountains stand high, because they are composed of breccia, which is highly resistant to weathering and erosion. Formations on either side of the breccia have been eroded away from flank of the mountains since Late Pliocene.

The marine terraces on the southwest face of the San Onofre Mountains appear to record a gradual decline of sea level since Late Pliocene. So far as can be determined, the terraces are undeformed. The lowest terrace is continuous along the coast except where interrupted by major drainage systems. The lowest terrace extends across the Cristianitos fault with no sign of displacement.

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CONCLUSIONS

1. The coastal area adjacent to the San Onofre Nuclear Generating Station appears to have been tectonically stable since Late Pliocene except for regional uplift relative to sea level.

2. The north-northwest-trending Cristianitos fault is the only major fault within the area. It is a normal dip slip fault with the west side down about 900 feet in the area between San Onofre and San Mateo Canyons. The fault has not moved since formation of the lowest marine terrace (about 120,000 years ago) and may have been inactive since Late Pliocene. The youngest formation known to be cut by the Cristianitos fault is the San Mateo Formation. Although the San Mateo Formation was previously considered to be younger than the Capistrano Formation, our study indicates it is a submarine channel backfill within the Capistrano Formation and is of Late Miocene to Early Pliocene age.

3. Four minor faults, including those referred to as the "E" and "F" faults have been mapped on the northwest flank of the San Onofre Mountains to the east of the Cristianitos fault. Each of these faults down drops Monterey Formation against San Onofre breccia. None of these faults shows evidence of Quaternary displacement. Three of the faults have Monterey Formation down dropped on their uphill (northeast) sides. The Monterey Formation has subsequently been stripped from the downhill side of the faults. The stripping occurred prior to the formation of a marine terrace at an elevation between

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800 and 900 feet above sea level. The terrace is probably of Late Pliocene age. Therefore, the faulting is probably of Late Pliocene or earlier age.

4. No significant faults, other than those noted above, have been recognized within the area between the coast and the San Onofre Mountains from the Cristianitos southeastward to Las Pulgas Canyon. There is continuity in the geologic structure between the San Onofre Mountains and the coast as shown by geologic cross sections CC', DD' and EE'. Variations in the lithology of the Monterey Formation in exposures along the coast is due to lateral facies changes rather than structural complications.

5. A distinctive tuff bed within the San Onofre breccia crops out in nine places over 2.5 miles extending on either side of Horno Canyon directly upslope from the lower marine terrace. All of the outcrops are in linear alignment, thus indicating an absence of significant cross faults in this area.

6. Marine terraces are well developed along the southwest flank of the San Onofre Mountains below an elevation of about 1500 feet above sea level. These terraces appear to reflect emergence of the coastal area following deep submergence during the Late Miocene and Early Pliocene. Terraces above an elevation of about 1500 feet are likely to be of Late Pliocene age. The terraces do not appear to be deformed or tilted.

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TABLE 1
SUMMARY OF PALEONTOLOGIC DATA

SAMPLE	FORMATION	AGE	STAGE	NORTH PACIFIC DIATOM ZONE	ENVIRONMENT	FORAMS	CALCAREOUS NANNO.	SILICEOUS MICROFOSSIL	Radiolaria	Diatoms	Silicoflag.	Ebridians.	MEGAFOSSILS	COORDINATES (in feet)*	MAP GRID LOCATION (in ft.)	
20D-1	Tm	Prob. Early Late Mioc.	Early Mohnian	17-20	----			X	X	X	X			N420,670 E1,633,230	SE 37,100'	NE 8,800'
26B-1	Tm	Prob. Late Miocene	Mohnian	14-20	Outer Neritic-Bathyal	X		X	X	X	X			N421,540 E1,621,100	SE 27,800'	NE 850'
26B-2	Qm	Quaternary	---	---	----								X	N424,265 E1,618,835	SE 24,260'	NE 1,170'
26C-1	Tm	Middle Miocene	Relizian-Luisian	---	Outer Neritic-Bathyal	X								N428,580 E1,615,030	SE 18,505'	NE 1,560'
26C-2	Qm	Quaternary	---	---	----								X	N425,640 E1,617,710	SE 22,480'	NE 1,360'
26C-3	Qm	Quaternary	---	---	----								X	N425,500 E1,617,850	SE 22,665'	NE 1,360'
27B-1	Tm	Prob. Early Late Mioc.	Early Mohnian	17-20	Outer Neritic-Bathyal	X		X	X	X	X			N421,550 E1,636,000	SE 38,420'	NE11,360'
33B-1	Tm	Early Middle Mioc.	Probable Luisian		Middle to Lower Bathyal	X	X▲							N431,980 E1,611,650	SE 13,675'	NE 1,605'
33D-1	Tm	Early Middle Mioc.	Luisian	20-23	Middle to Lower Bathyal	X	X▲	X*	X	X	X	X		N435,620 E1,607,110	SE 7,870'	NE 1,000'
33D-2	Tm	Middle Miocene	Luisian	20-23	Middle Bathyal	X		X	X	X	X			N435,360 E1,607,400	SE 8,250'	NE 1,025'
33D-3	Tm												X	N435,840 E1,610,200	SE 9,880'	NE 3,340'
33D-4	Tm	Barren	---	---	----								X	N436,370 E1,608,820	SE 8,560'	NE 2,750'
41A-1	Tm	Barren	---	---	----									N437,730 E1,604,820	SE 4,750'	NE 900'
41A-2	Tm	Barren	---	---	----								X	N440,370 E1,605,540	SE 3,370'	NE 3,270'
41A-3	Tm	Middle Miocene	Probabl Luisian	20-23	----			X*	X	X	X	X		N440,385 E1,605,190	SE 3,100'	NE 3,075'
41A-4	Tm	Prob. Early Late Mioc.	Early Mohnian	17-20	Outer Neritic-Bathyal	X		X	X	X	X			N437,190 E1,605,660	SE 5,720'	NE 1,075'
41B-1	Tm	Middle Miocene	Probable Luisian	20-23	----			X*	X	X	X	X	X	N438,710 E1,606,080	SE 4,950'	NE 2,480'
41B-2	Tm	Middle Miocene	Luisian	20-23	----			X	X	X	X			N438,940 E1,609,180	SE 6,990'	NE 4,805'
41C-1	Tm	Middle Miocene	Probable Luisian	20-23	----			X*	X	X	X	X		N441,930 E1,605,120	SE 1,950'	NE 4,080'
41C-2	Tm				----								X	N444,910 E1,605,460	SE 140'	NE 6,480'
49A-1	Tm	Early Middle Mioc.	Luisian	20-23	Probable Middle Bathyal	X	X	X	X	X	X			N447,240 E1,602,965	NW 3,325'	NE 6,330'
49C-1	Tm	Late Miocene	Late Mohnian	13-16	----			X	X	X	X			N451,500 E1,602,140	NW 6,870'	NE 8,710'
49C-2	Tm	Prob. Early Mid. Mioc.	Luisian	20-23	Middle Bathyal	X	X	X	X	X	X			N452,020 E1,602,940	NW 6,690'	NE 9,720'
57B-1	Tm	Late Miocene	Mohnian	15-18	----			X	X	X	X			N454,685 E1,599,180	NW 11,270'	NE 8,900'
57B-2	Tm	Late Miocene	Mohnian	15-20	----			X	X	X	X			N454,935 E1,599,190	NW 11,470'	NE 9,100'
57D-1	Tc	Prob. Late Miocene	---	---	----			X	X	X	X			N458,250 E1,595,195	NW 16,660'	NE 8,650'
57D-2	Tc	Prob. Late Miocene	---	---	----			X	X	X	X			N458,565 E1,596,020	NW 16,330'	NE 9,510'
58A-1	Tm	Early Middle Mioc.	Luisian	20-23	Middle Bathyal	X	X▲	X	X	X	X			N454,790 E1,601,840	NW 9,530'	NE10,890'
SO2/3 1,2	Tsm	Barren	---	---	----				X					N439,800 E1,602,450		
SO2/3 3,4	Tsm	Barren	---	---	----									N437,560 E1,604,700		

*California Grid Zone 6

Note - Prob.= Probable
Mioc.=Miocene
All the above ages are "Provincial"

*These samples have nearly identical siliceous microfossil assemblages
▲These samples have nearly idential nannofossil (calcar.) assemblages

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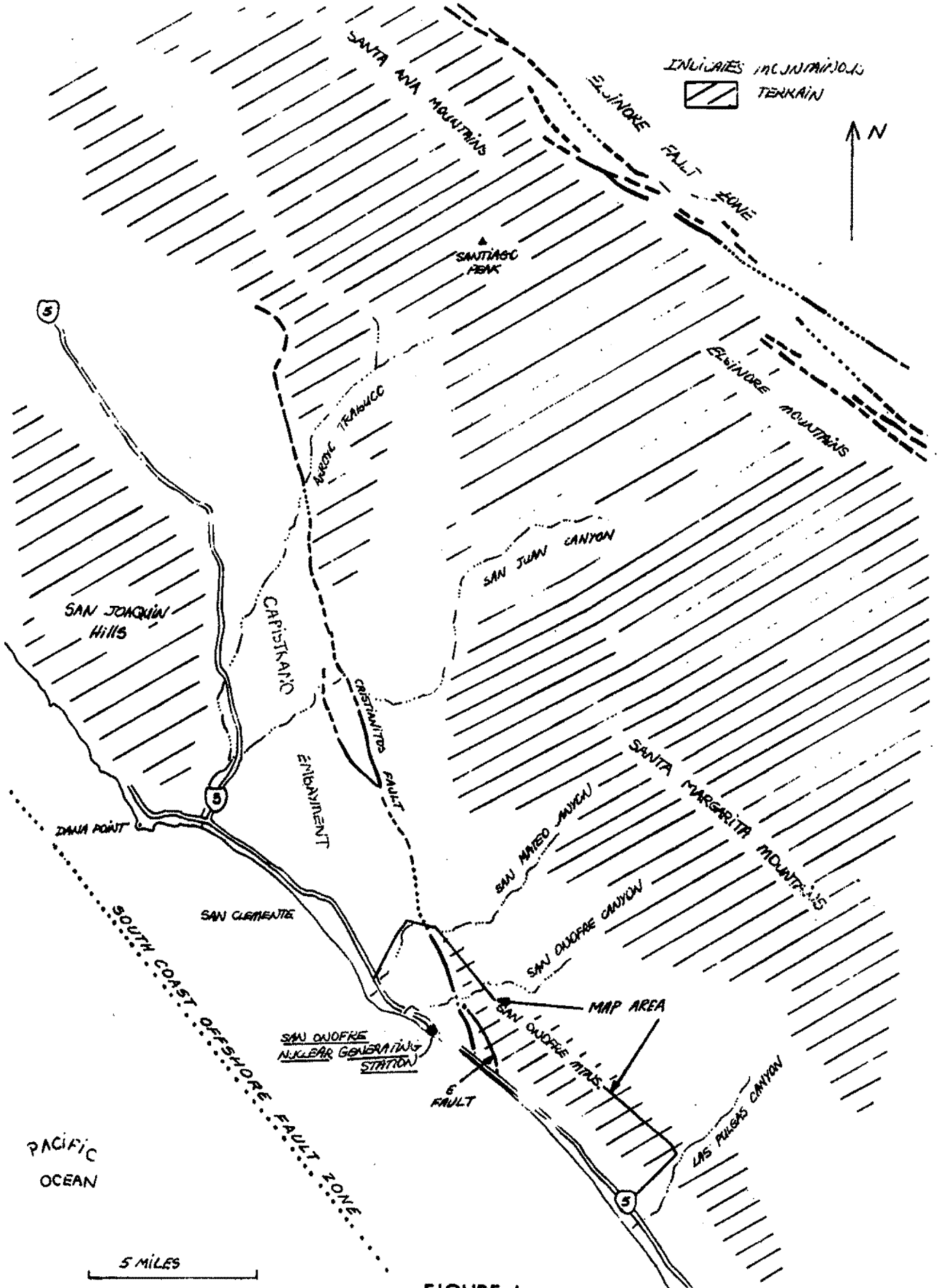

FIGURE 1
LOCATION MAP

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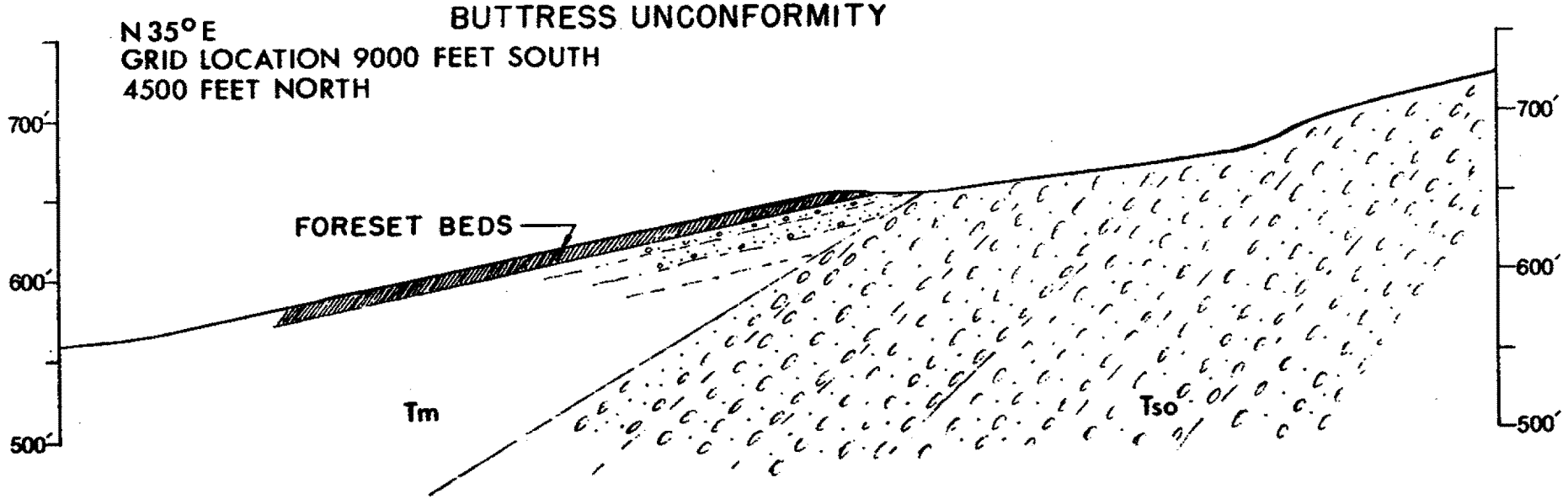
FIGURE 2

FORESET BEDS NEAR MONTEREY
BUTTRESS UNCONFORMITY



SCALE: 1" = 100'

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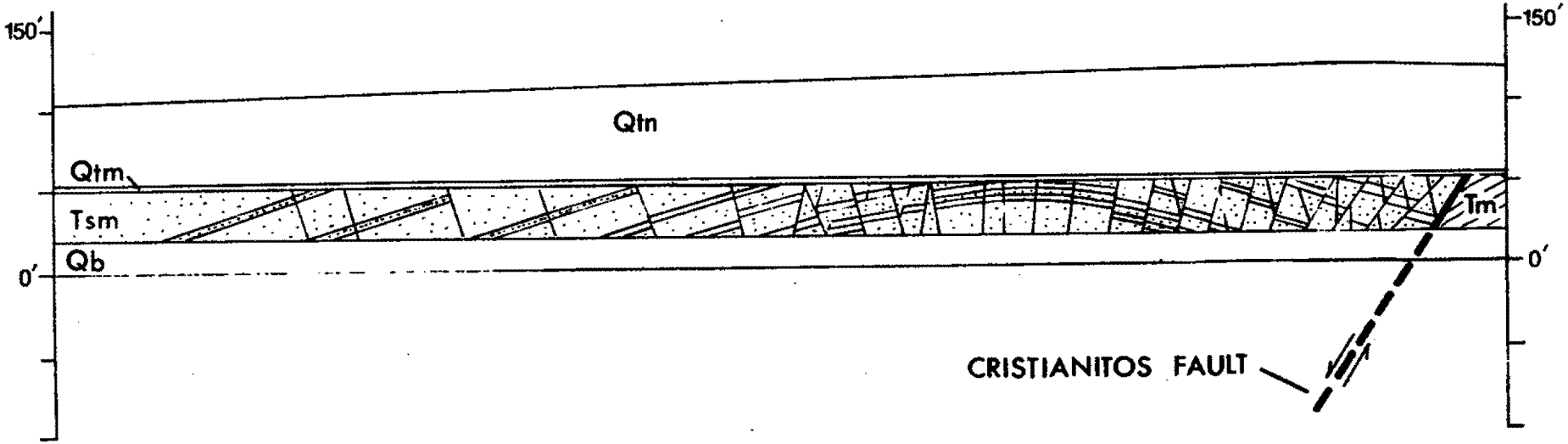
FIGURE 3. FOSSIL LOCATIONS

FIGURE 4

REVERSE DRAG FEATURES AT THE CRISTIANITOS FAULT
LOOKING NORTH



SCALE: 1" = 100'

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EXPLANATION

QUATERNARY

Holocene

- **Qb** — Beach sand and gravel
- **Qal** — Alluvium - silt, sand, gravel, cobbles and boulders
- **Qal/Qtn/Qtm** — Alluvium overlying marine and nonmarine deposits
- **Qls** — Landslide
- **Qtr** — Terrace - recent river deposits
- **Qtn** — Terrace deposits - nonmarine
- **Qtm** — Terrace deposits - marine

Pleistocene

- **Qtn/Qtm** — Terrace deposits - nonmarine overlying marine

TERTIARY

Lower Pliocene

Unconformity

- **Tsm** — San Mateo Formation - light gray arkosic sandstone, massive to thickly bedded well consolidated. Deposited contemporaneously with Capistrano Formation.

Unconformity

Middle to upper Miocene

- **Tm** — Monterey Formation - basal coarse grained sandstone and conglomerate with pectin and oyster beds, diatomaceous siltstone and thin bedded sandstone

Unconformity

- **Tso** — San Onofre Formation - dark gray to brown gray breccia and conglomerate characterized by clasts of blue green glaucophane schist, local outcrops of gray brown medium to coarse grained sandstone

Unconformity

Eocene

- **Tlj** — La Jolla Group - consists of Santiago Formation, gray massive arkosic sandstone, uncemented, and Silverado Formation, marine and nonmarine micaceous sandstone, siltstone, conglomerate and minor thin claystone and coal

SYMBOLS

- Contact between rock units, dashed where approximately located, dotted where inferred
- Fault, dashed where approximately located, dotted where inferred D - downthrown side, U - upthrown side
- 49C-2 — Fossil locality
- 25 — Strike and dip of joint plane
- 19 — Strike and dip of bedding
- Horizontal beds
- 10 / 21 — Strike and dip of fault plane with plunge of slicken sides
- Landslide, arrow marks direction of slide
- Ancient beach bar in a terrace deposit
- Tuff
- Syncline
- A A' — Location of cross section

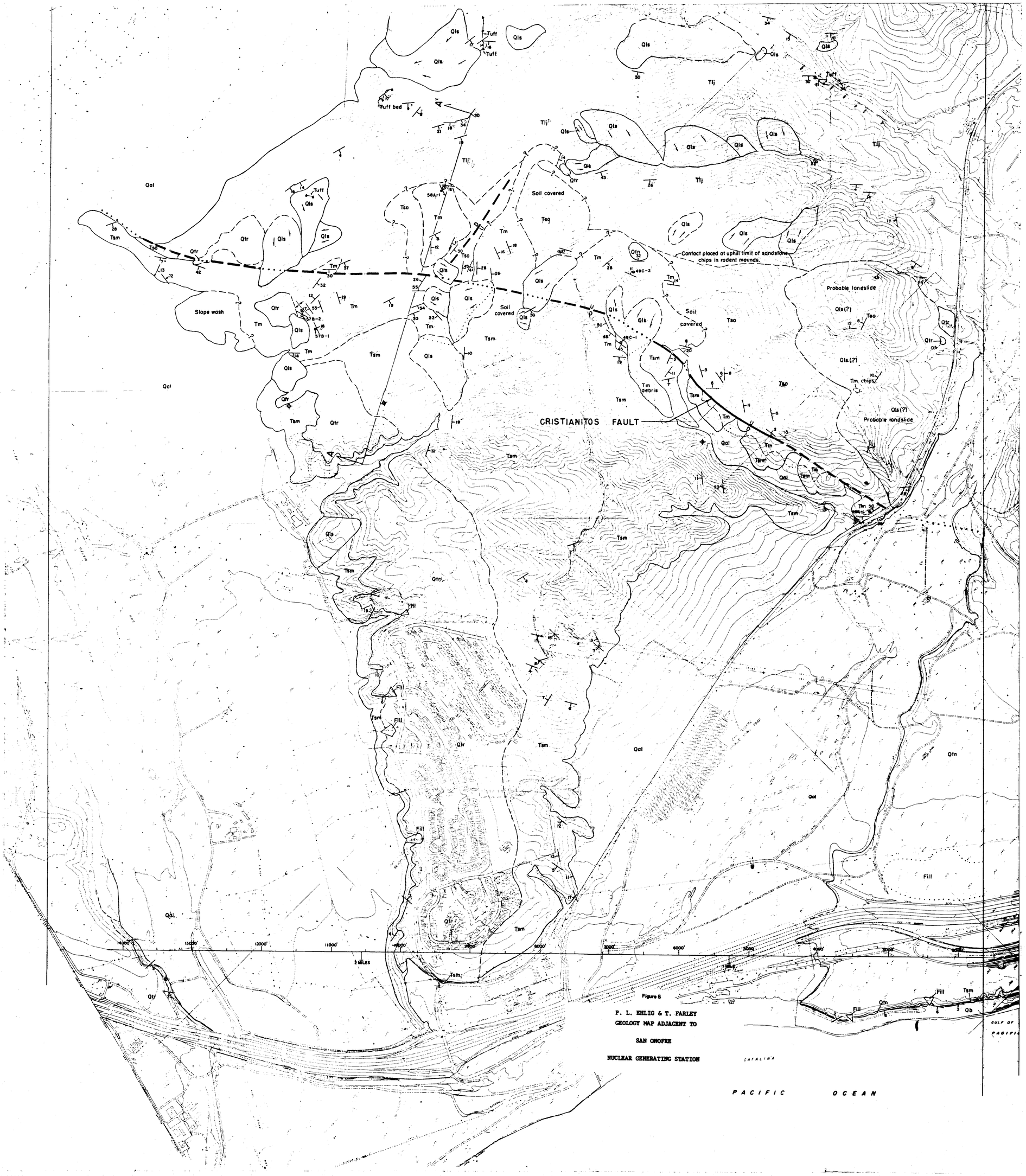

Figure 5

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GEOLOGY MAP ADJACENT TO
SAN ONOFRE
NUCLEAR GENERATING STATION

0 200 400 600 800 1000
SCALE IN FEET

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Figure 6

P. L. EHLIG & T. FARLEY
GEOLOGY MAP ADJACENT TO

SAN ONOFRE

NUCLEAR GENERATING STATION

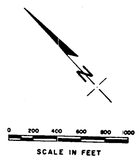

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Figure 7

P. L. EHLIG & T. FARLEY
GEOLOGY MAP ADJACENT TO
SAN ONOFRE
NUCLEAR GENERATING STATION

N

0 200 400 600 800 1000
SCALE IN FEET

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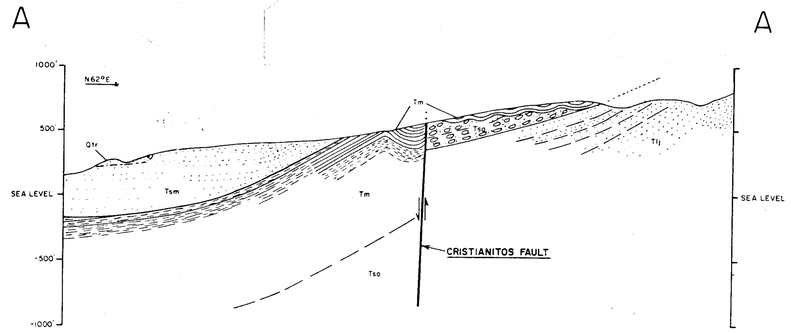

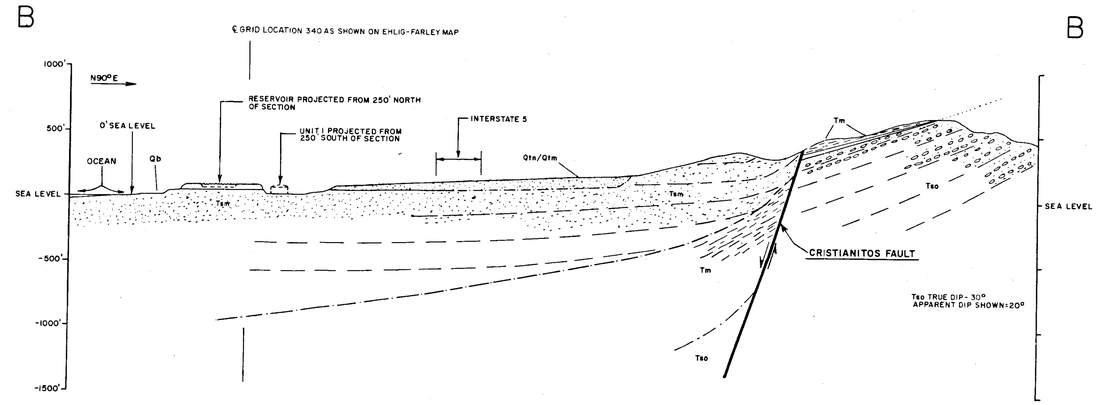

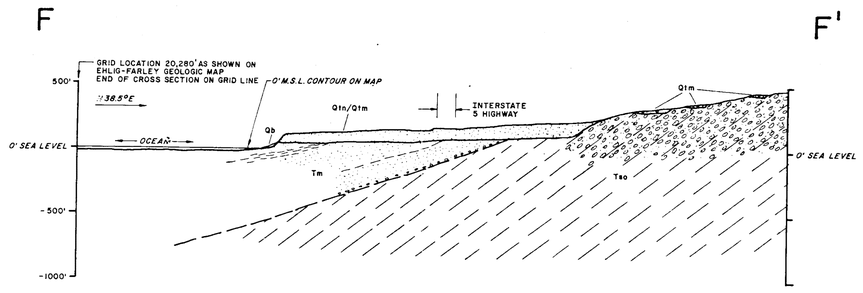

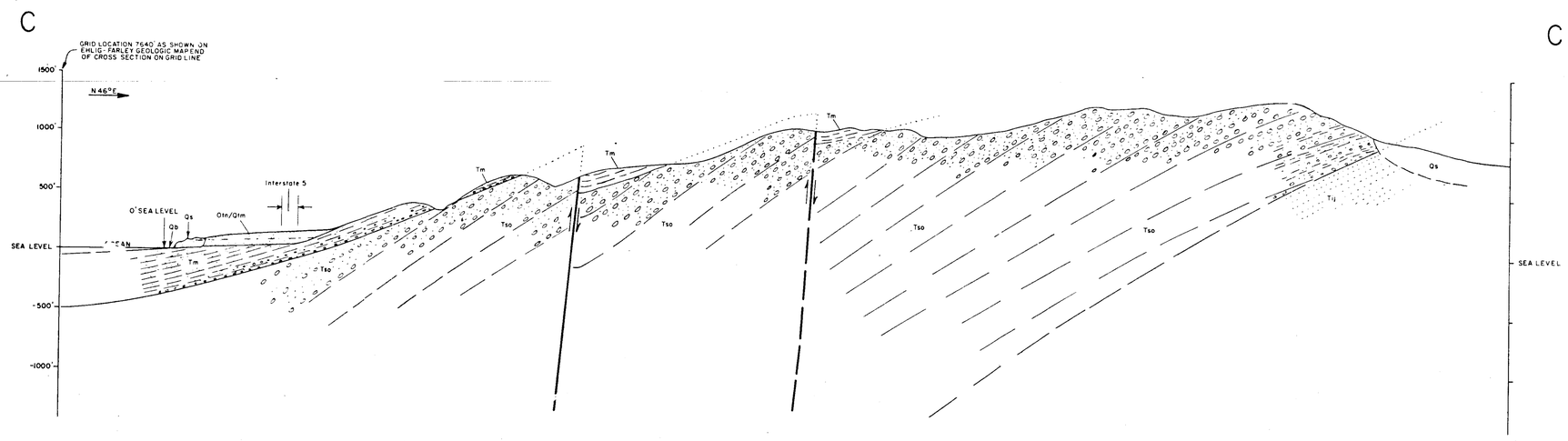

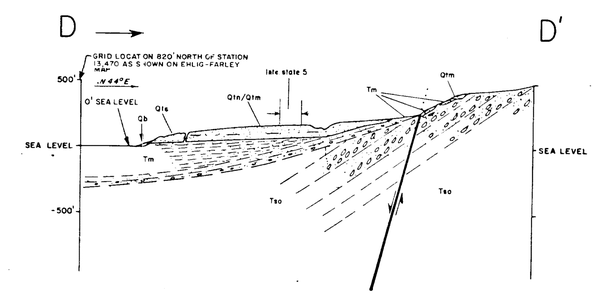

SCALE: 1" = 500'

EXPLANATION: SEE GEOLOGIC MAP

Figure 8

P. L. EHLIG & T. FARLEY
GEOLOGIC SECTIONS ADJACENT TO
SAN ONOFRE
NUCLEAR GENERATING STATION

GEOLOGIC CROSS-SECTIONS
A-A'; B-B'; C-C'; D-D';
F-F'

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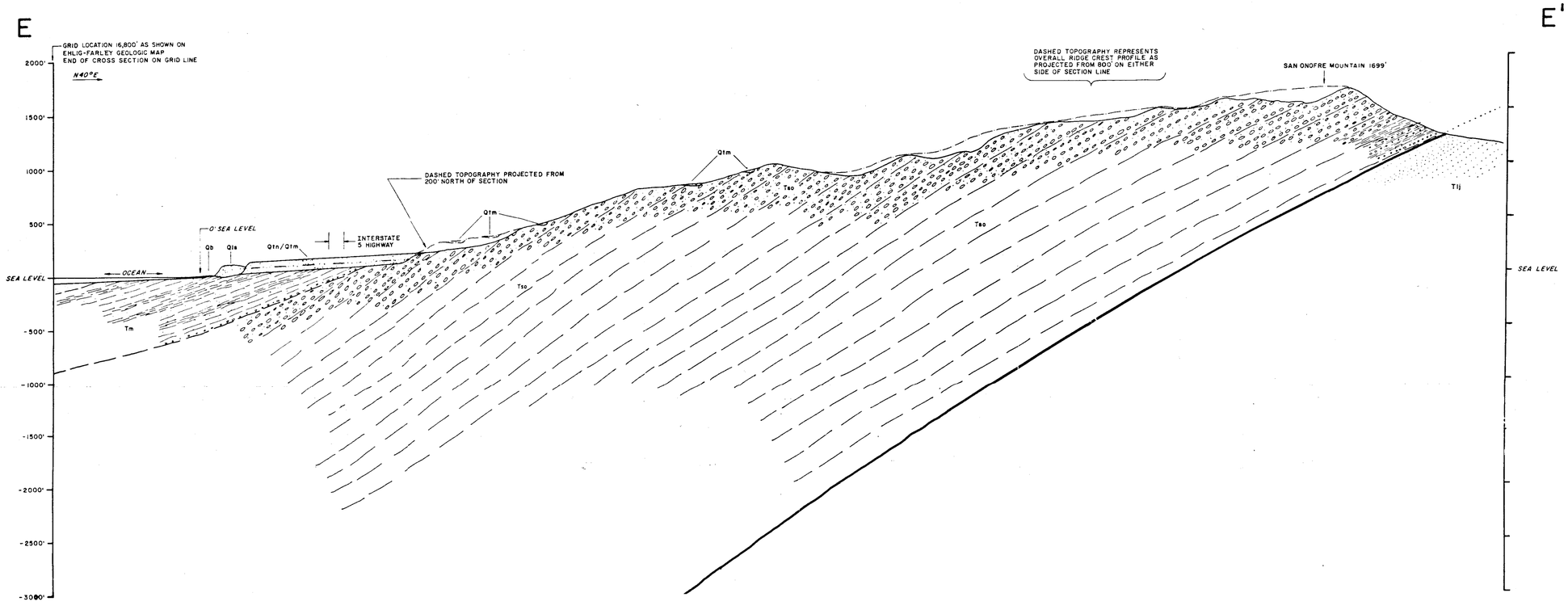

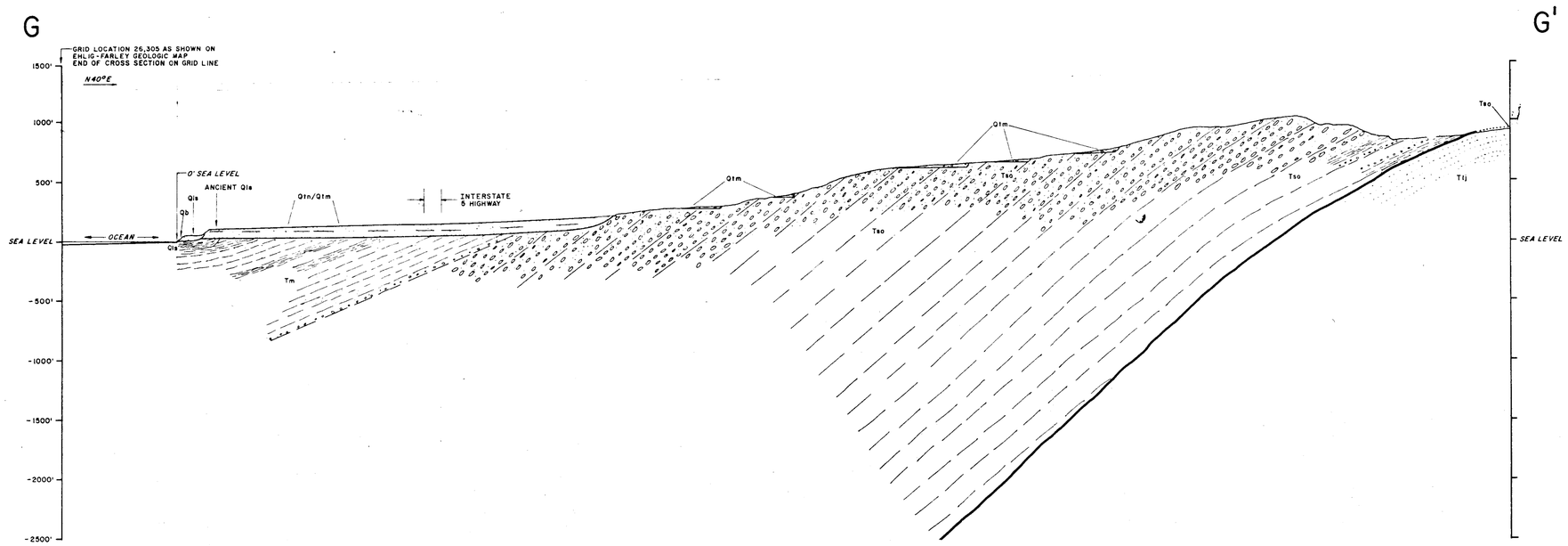

SCALE: 1" = 500'

EXPLANATION: SEE GEOLOGIC MAP

Figure 9

P. L. EHLIG & T. FARLEY
GEOLOGIC SECTIONS ADJACENT TO
SAN ONOFRE
NUCLEAR GENERATING STATION

GEOLOGIC CROSS-SECTIONS
E-E' AND G-G'

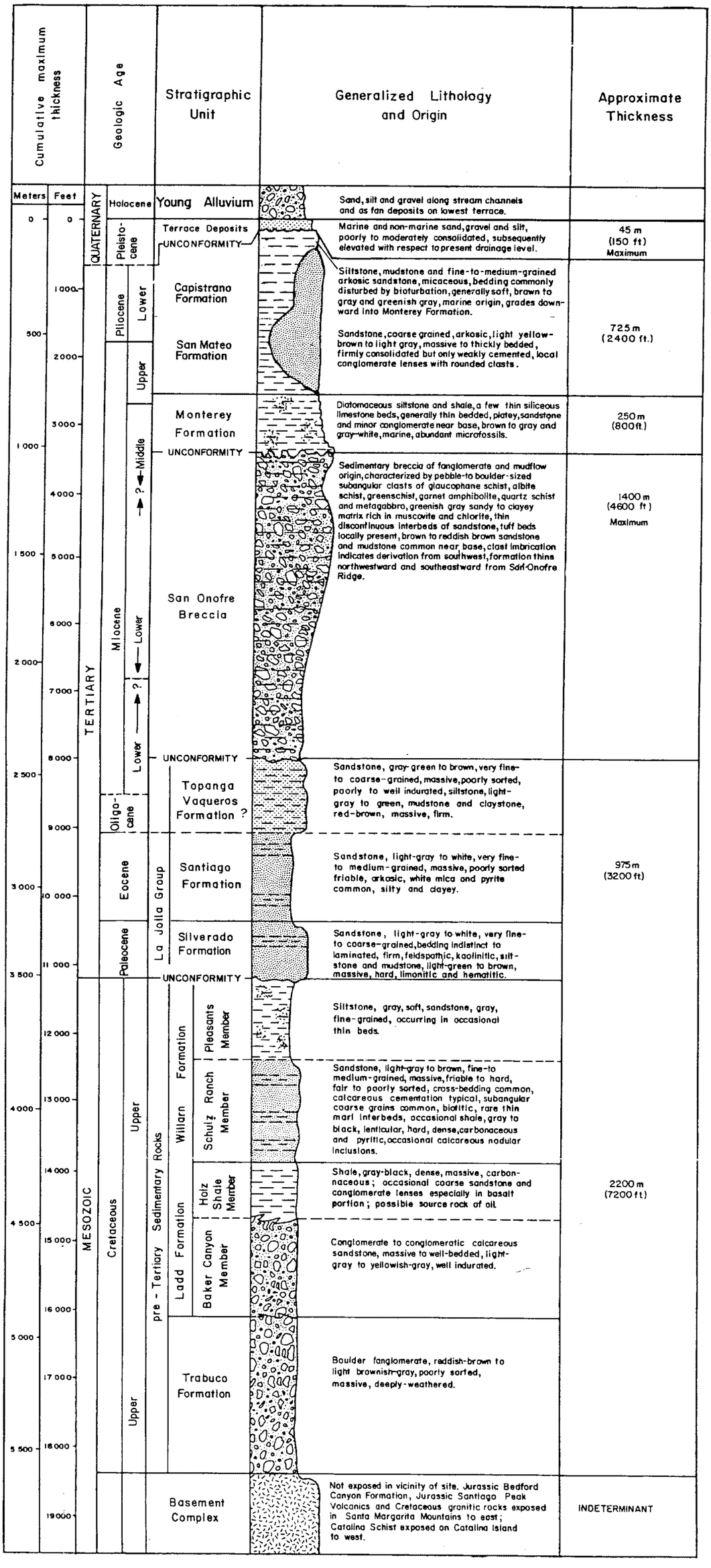

Figure 10

COLUMNAR SECTION

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APPENDIX 2.5G

GENERALIZED SUB-SURFACE GEOLOGICAL AND GEOPHYSICAL STUDY CAPISTRANO AREA ORANGE COUNTY, CALIFORNIA NOVEMBER 1975

Site File Copy

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GENERALIZED SUB-SURFACE

GEOLOGICAL AND GEOPHYSICAL STUDY

CAPISTRANO AREA

ORANGE COUNTY, CALIFORNIA

NOVEMBER 1975

Amended: April 2009 TL: E048000

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INTRODUCTION

This study has been conducted for the Southern California Edison Company to investigate and acquire certain basic geophysical and geologic well data held by various oil companies, and to prepare a sub-surface contour map with appropriate geologic structure sections in the vicinity of the Capistrano embayment with emphasis on the area adjacent to the Cristianitos Fault. The purpose of this study is to provide more information that would aid toward understanding of recent seismic activity as it might relate to any geologic structure in the area.

REGIONAL GEOLOGIC SETTING

In general, this area of study, covering about 350 square miles, lies in a synclinal area between a large structurally complicated uplift, the San Joaquin Hills, on the west, and a much larger uplift, the Santa Ana Mountains, to the north and east. Within the central part of the area of study lies the Capistrano embayment (relating to the local distribution of Middle and Late Miocene sediments) along which trends the Cristianitos Fault in an approximate N 5-20° W direction. The Pacific Ocean lies to the south.

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GEOPHYSICAL DATA

An extensive search for geophysical data among oil companies has been conducted. The results of this investigation are shown on Exhibit A, which illustrates the source, kind, and location of geophysical data. The area of gravity and air magnetic coverage is shown in an insert in the lower part of the map. Shell seismic work is available by purchase only through the Geophysical Trade Service in Houston. A few records from one Shell line were examined. The data appeared very poor. Considerable effort was made to acquire Exxon's (Humble) seismic data by trade and/or purchase. It was found that Exxon had lost their records on lines D 64, 65, and 66, and they have no interest in selling or trading their lines D 62 or D 63. Standard Oil seismic is all available for purchase through Geodata in Denver. This data was briefly examined in Standard Oil's San Francisco office. It is old work, and Standard had processed only one line (No. N-147) through modern computers. Useable data is present on this line, but its location is several miles from the Cristianitos Fault, and accordingly, it is of little or no value toward the purpose of this report.

At this time the following geophysical surveys have been acquired, by trade. They have been turned over to Dr. Shawn Biehler, University of California at Riverside, for further study.[1]

---

(1) Dr. Biehler's evaluation of these surveys is included in Enclosure 4 of this report.

1. Standard Oil Gravity Data (820 Gravity Stations)
   Preliminary examination of this work suggests a general confirmation of the geologic interpretation as presented below.[2]

2. Gulf Oil Air Magnetic Data (2,100 line miles)
   Preliminary examination of this work, also in general, confirms the geologic interpretation as presented below.[2]

3. Mobil Oil Seismic Line
   Initial negotations of trade for this line set forth nine miles of line along the Ortega Highway (Highway 74) where the westward one mile extended west one mile of the surface trace of the Cristianitos Fault and eastward one mile of the line ended close to the contact of the Cretaceous sediments with the Basement Complex. However, it has been later ascertained that the useable data, which is sparse, includes only seven miles, excluding one mile on each end of the line. The contractor for this line was GSI (Geophysical Service Incorporated), and the line was run in 1971. The energy source was VIBROSEIS, which involves a surface "thumper", in contrast to setting off a charge in a shallow (50 - 100') shot hole, thereby recording sound energy reflected back to surface seismometers from the various formations.

   Although the data from this line is meager, initial examination appears to confirm the present subsurface geologic interpretation.

---

(2) Final examination of this work is included in Enclosure 4.

In addition to the above geophysical trades, a Standard Oil seismic line, N-152, which crosses the Cristianitos Fault, was purchased. This line was shot in 1954. Western Geophysical was the contractor. The records have recently been re-processed in Houston by Western using modern methods--resulting in a non-migrated record section. The data is poor, but helps to confirm the general geologic interpretation.

Western attempted to apply migration to this section by modern methods, but due to steep dips and refractions their efforts were unsuccessful.

GEOLOGIC DATA

The geologic interpretation as set forth by illustrations (structure sections and map) accompanying this report is based upon published surface geology and proprietary subsurface oil well and core hole data. The source of the oil well and core hole data consists of various major and independent oil companies who have released the information to the writer and to other individuals who have in turn passed the information on to the writer. Much of this data was obtained prior to commencement of this particular study for other purposes, but that part has been used to complete this current study.

More specifically, the geologic sub-surface well data consists of the following items where either all or part of this list for any one oil well or core hole is present in the basic files used for this report.

1. Electrical Surveys
   This includes a variety of logs such as the electric log, sonic or density log, micro-log, or dipmeter.

2. Well History
   In addition to the chronological events involved in drilling a well, this generally includes such information as the description of cores and side wall samples taken from the bore hole, and results of formation tests.

3. Paleontological Data
   This may be mentioned in the well history as a formation contact point based upon the operator's paleontological report or it may be the actual paleontological report by the operator's paleontologist. Also, the data may have been acquired independently from sources other than the operator of the particular well.

4. Mud Logs
   These logs show lithology, drilling rates, oil and gas showings and other miscellaneous information helpful toward evaluation of the rocks penetrated by the bore hole.

5. Cable Tool Logs
   These are confined to old wells when modern technical methods of evaluation of bore holes had not been developed. They are usually a description of the lithology encountered and described by the driller.

Various data pertaining to one or more of the above kinds have been obtained from 118 wells (abandoned oil wells or core holes) which include all of the wells pertinent to the area of study.

GEOLOGIC INTERPRETATION

Five structure sections and a sub-surface contour map were prepared to illustrate the general sub-surface geology. These have been included as Exhibit B, and Structure Sections A-B, C-B, D-E, F-G, and H-G.

A discussion of each of these illustrations follows:

EXHIBIT B - Generalized Contours on Base of Tertiary or Top of Cretaceous

This map is designated "generalized" due to the large area contoured and the fact that only twenty one control points from wells that reached the Cretaceous are present. Due to the lack of paleontological data, some of these points are interpretative. Estimated points from five additional holes were also used. This horizon was chosen as best for depicting the regional structure at depth. The map is further supported by surface geology and thickness estimates of the younger formations overlying the Cretaceous.

Shown on the eastward portion of this map are the areas where Cretaceous sediments and the Basement Complex are exposed at the surface forming the western slope of the Santa Ana Mountains. The surface contact between the

overlying Tertiary sediments and the Cretaceous is a fault contact over most of the outcrop area. The fault is called the Mission Viejo Fault and the youngest rocks cut by the fault are Eocene in age. Moving westward on the map the contours show a general bowing structure that plunges to the southwest. These contours are interrupted by a large normal fault, the Cristianitos Fault, which has a "down-to-the-west" movement, trending in a N 5° - 20° W direction through the central part of the mapped area.

Immediately westward of the Cristianitos Fault Zone, the structure at Cretaceous depth is homoclinal to the west--except in the south central part of the map (central part of T 8 S - R 7 W) where a faulted anticlinal structure west of the Cristianitos Fault is present. A minor amount of oil (non-commercial) has been recovered from three abandoned oil wells on this structure from sands of Cretaceous age.

The oil is trapped partly by stratigraphy within the Cretaceous beds, partly by the faulted anticlinal structure and partly by the Cristianitos Fault.

The central structure of the mapped area consists of a regional syncline which is bifurcated in the northwestern part of the map by a southerly plunging faulted anticline that culminates in a local area in T 5 S, R 8 W, where Cretaceous rocks locally crop out. This anticline is approximately on trend with the faulted anticlinal structure mentioned above. The regional syncline plunges to the southeast and to the northwest in areas within the east central part of T 7 S, R 8 W, resulting in a low basinal structure about a mile northwest of the January 1975 earthquake epicenters.

The eastern flank of the San Joaquin Hills is in the area between Highway 5 and the shoreline, within the southwestern portion of the map. The general structure at Cretaceous depth in this area is a faulted northeast dipping homocline, which terminates at the regional syncline axis discussed above. The Shady Canyon Fault is an old prominent and large fault that is exposed at the surface in the San Joaquin Hills. This fault can be traced on the surface into the most western part of the mapped area where it is covered at the surface by beds of Upper Miocene and Pliocene Age. Due to the apparent magnitude of it's displacement (4,000± feet) it is interpreted as continuing to the southeast as shown. No well data at Cretaceous depth to support this interpretation is present.

Some of the additional faulting at Cretaceous depth is based upon surface mapping, particularly in the vicinity immediately west of the Cristianitos Fault. Worthy of note is that the direction of faulting tends to merge into and parallel the strike of the Cristianitos Fault in the southern part of the mapped area.

CRISTIANITOS FAULT

This fault extends southeasterly from the southeast part of T 5 S - R 8 W a distance of about 24 miles to a point about 3/4 mile east of the San Onofre Nuclear Generating Plant, and then continues southeasterly a few miles offshore. Over the distance

onshore the well control is sparse for mapping this fault in the sub-surface where it intersects the base of the Tertiary and/or the top of the Cretaceous. Actually, there are only three abandoned exploratory holes (wells) that have penetrated the fault. These are as follows:

1. ERA Oil Company "Glenn Ranch" No. 2-1, Section 8, T 6 S, R 7 W.

2. Exxon (Humble) "O'Neill Estate" No. C-1, Section 15, T 8 S, R 7 W.

3. Texas "O'Neill Estate" No. 1-1, Section 22, T 8 S, R 7 W.

However, other factors that support the general position of the fault at Cretaceous depth are--

1. The surface trace of the fault where the fault has been mapped by others cited in references noted on the accompanying structure sections and map.

2. Information from exploratory holes within approximately one-half mile on either side of the fault. These holes are ten in number and they aid in mapping the fault.

3. Geophysical data.

In the few cases where wells have penetrated the fault the apparent dip of the fault from the surface trace to the point in the well varies between 60 and 70

degrees. There is little or no control at depth except the proximity of some of the non-faulted deeper holes within one-half mile of the fault suggests that the dip may steepen at depth. The accompanying structure sections show the fault zone to steepen, in general, to 75° - 80° westward in the deeper part of the sedimentary column.

The fault is complicated by en-echelon slivers and branches forming a fault zone which at the surface is in places as wide as 2,000 feet. The largest branch, in the vicinity of Sections 4, 9, and 10 of T 8 S - R 7 W, and Sections 28 and 33 of T 7 S, R 7 W, has been called the Forster Branch by others, and it is separated horizontally on the surface from the main branch by as much as 5,500 feet.

The displacement on the Cristianitos Fault appears to be essentially vertical and it is "down-to-the-west." The amount of vertical separation is variable but appears to decrease at the north end and the south end (near San Onofre) with the greatest displacement in the central part of its length onshore. The greatest vertical separation is between 3,500 and 4,000 feet in the area of Sections 20, 21, 28, and 29, T 7 S, R 7 W, where the north end of the Forster Branch merges with the Cristianitos Fault. In the central part of T 8 S, R 7 W, where a faulted anticlinal structure is present west of the Cristianitos Fault, the vertical separation reaches a maximum of about 2,500 feet. It decreases to about 1,700 feet where Highway 74 (Ortega Highway) crosses the fault.

This decrease is associated with additional "down-to-the west" displacement on the Forster Branch. The estimates of the amount of displacement on the fault are generally supported by the contours on top of the Cretaceous on either side. However, due to lack of additional sub-surface control, the amount of displacement over its entire length is approximate.

STRUCTURE SECTIONS - A-B, C-B, D-E, F-G, and H-G

The general stratigraphy of the area covered by this study is demonstrated by the above structure sections. For the most part the sections are self-explanatory. This report does not include a description of the various formations since they have been defined and discussed by authors of surface geology as cited on the sections. Although these sections do not pass through all sub-surface well control, the more important holes are included. The main purpose of the sections is to illustrate the interpretation of the Cristianitos Fault Zone at depth and to define the sedimentary column. Sections A-B and C-B are more regional and aid in the definition of the geologic setting. Sections D-E and particularly F-G and H-G show specific data that support the amount of displacement of the Cristianitos Fault at those locations.

It can be readily seen that information at depth is sparse and that the geology at depth is thereby

highly interpretative. However, formation thicknesses have been studied and applied to the various sections to maintain a continuity of thickening and thinning based upon electric log correlation, age determination by paleontological data, and isopachs of local member and formation units.

Where available, reduced electric log curves and dipmeter are plotted to aid in the final interpretation.

CONCLUSION

An investigation of existing geophysical work within the area of study has been made and recorded on Exhibit A of this report. Examination by the writer indicates that the geophysical data that has been gathered confirms the geologic interpretation as illustrated in the accompanying Exhibits. Further geophysical study by Dr. Shawn Biehler is in progress.(3)

The Cristianitos Fault is a normal fault which dips between 60° and 75° to the west with essentially only vertical displacement "down-to-the-west." The greatest vertical separation occurs in the vicinity of the central part of its onshore length where it varies between 1,700 and 4,000 feet. The shallower dip of the fault appears to be at or near the surface with steeper dip at depth. The fault is complicated by fault slivers en-echelon to the main trace and by other faults at angles to and merging into the main trace. No significant movement along the Cristianitos Fault appears to have occurred since Late Pliocene time.

---

(3) This study has been completed and is reported in Enclosure 4.

This study does not indicate that the source of the two epicenters plotted within the south one-half of Section 25, T 7 S, R 8 W, is from any movement on the Cristianitos Fault. In fact, there is no substantial evidence that any structure as interpreted by this study is compatible with these epicenters except that their location is in a general way coincident with the lowest part of the Capistrano Basin. Accordingly, one explanation of the source of the epicenters may be differential settling within the basin.

Jack C West

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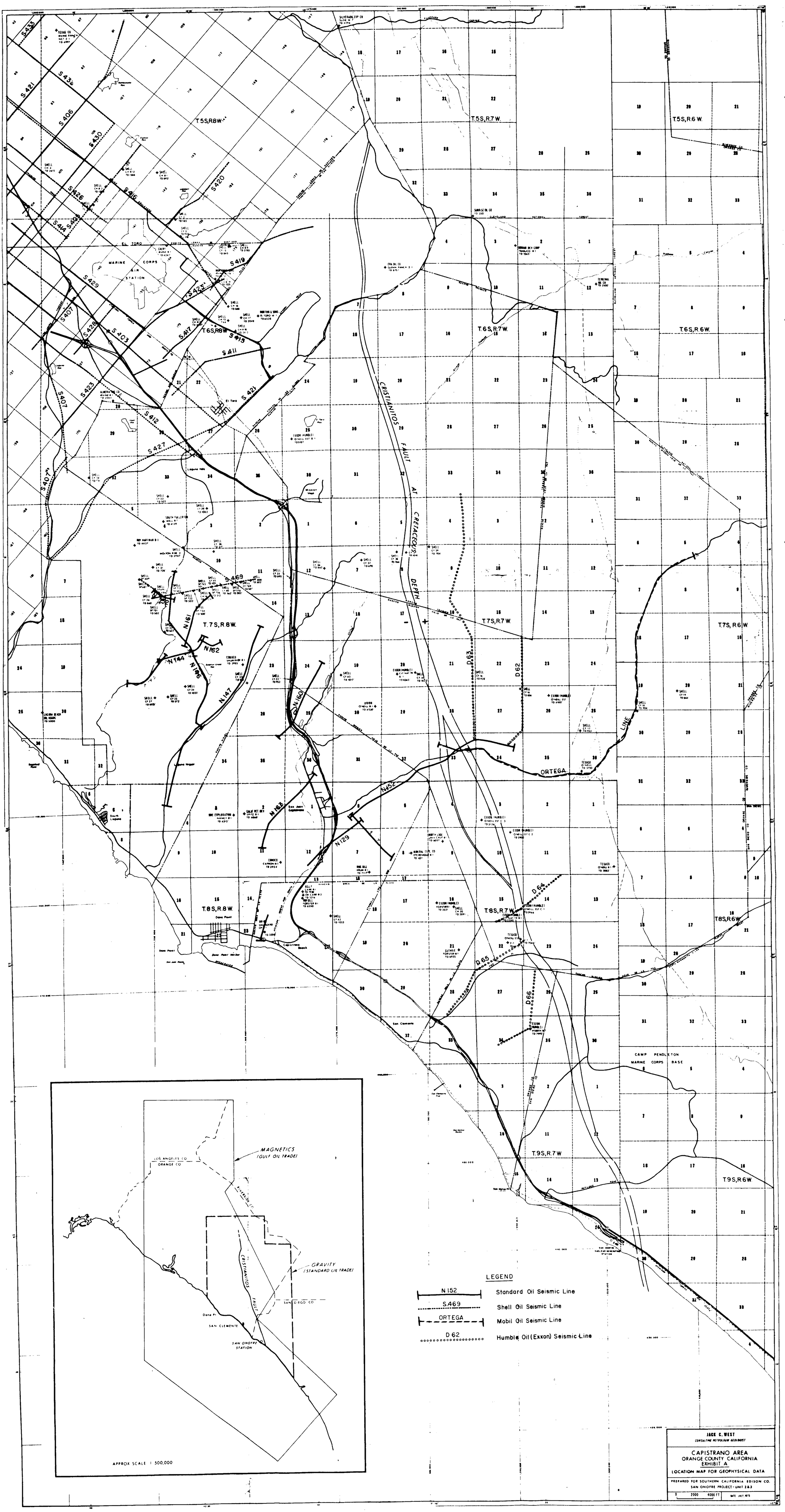

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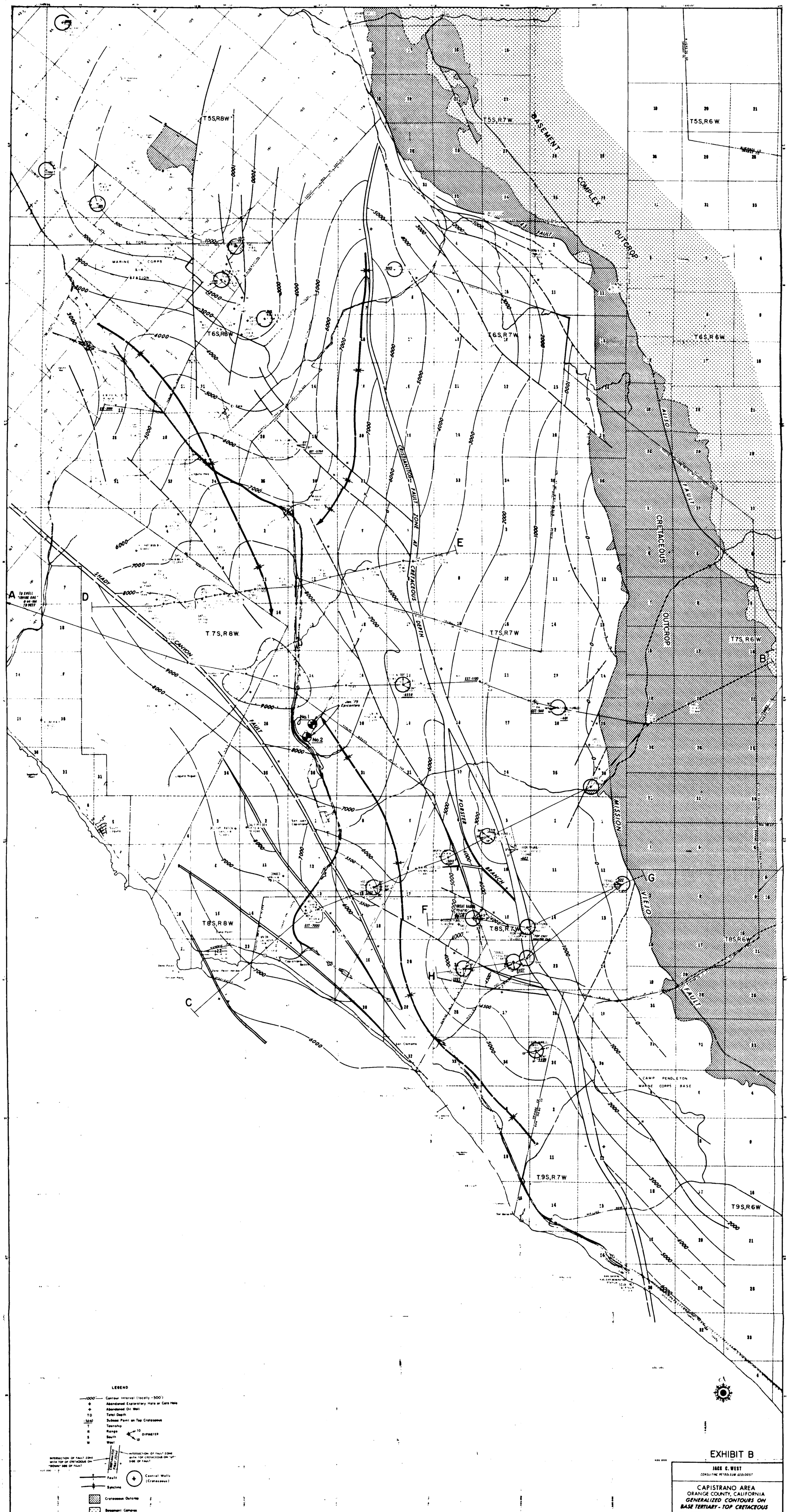
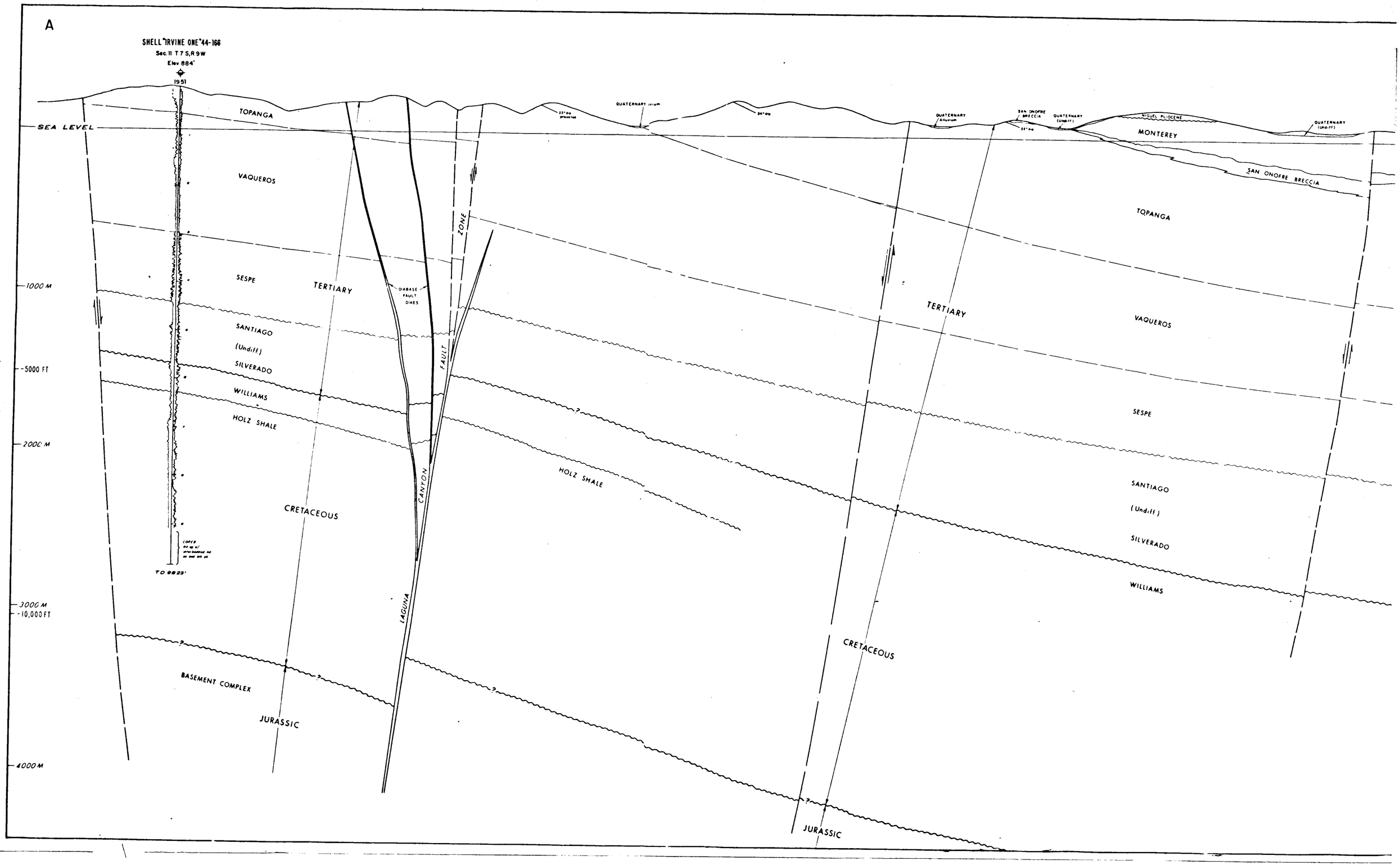

T5S,R8W
T5S,R7W
T5S,R6W
BASEMENT COMPLEX OUTCROP
MARINE CORPS BASE
T6S,R8W
T6S,R7W
T6S,R6W
CRETACEOUS OUTCROP
ALISO FAULT
CORONADO FAULT ZONE W. CRETACEOUS DEPTH
T7S,R8W
T7S,R7W
T7S,R6W
SLAUGH CANYON FAULT
No. 1
No. 2
FORSTER LOOP BRANCH
MISSION VIEJO FAULT
T8S,R8W
T8S,R7W
T8S,R6W
CAMP PENDLETON MARINE CORPS BASE
T9S,R7W
T9S,R6W
A
B
C
D
E
F
G
H
LEGEND
Contour Interval (locally = 500')
Abandoned Exploratory Hole or Core Hole
Abandoned Oil Well
Total Depth
Subsea Point on Top Cretaceous
Township
Range
South
West
Fault
Syncline
Cretaceous Outcrop
Basement Complex Outcrop
EXHIBIT B
JACK E. WEST
CONSULTING PETROLEUM GEOLOGIST
CAPISTRANO AREA
ORANGE COUNTY, CALIFORNIA
GENERALIZED CONTOURS ON
BASE TERTIARY - TOP CRETACEOUS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TOPANGA
VAQUEROS
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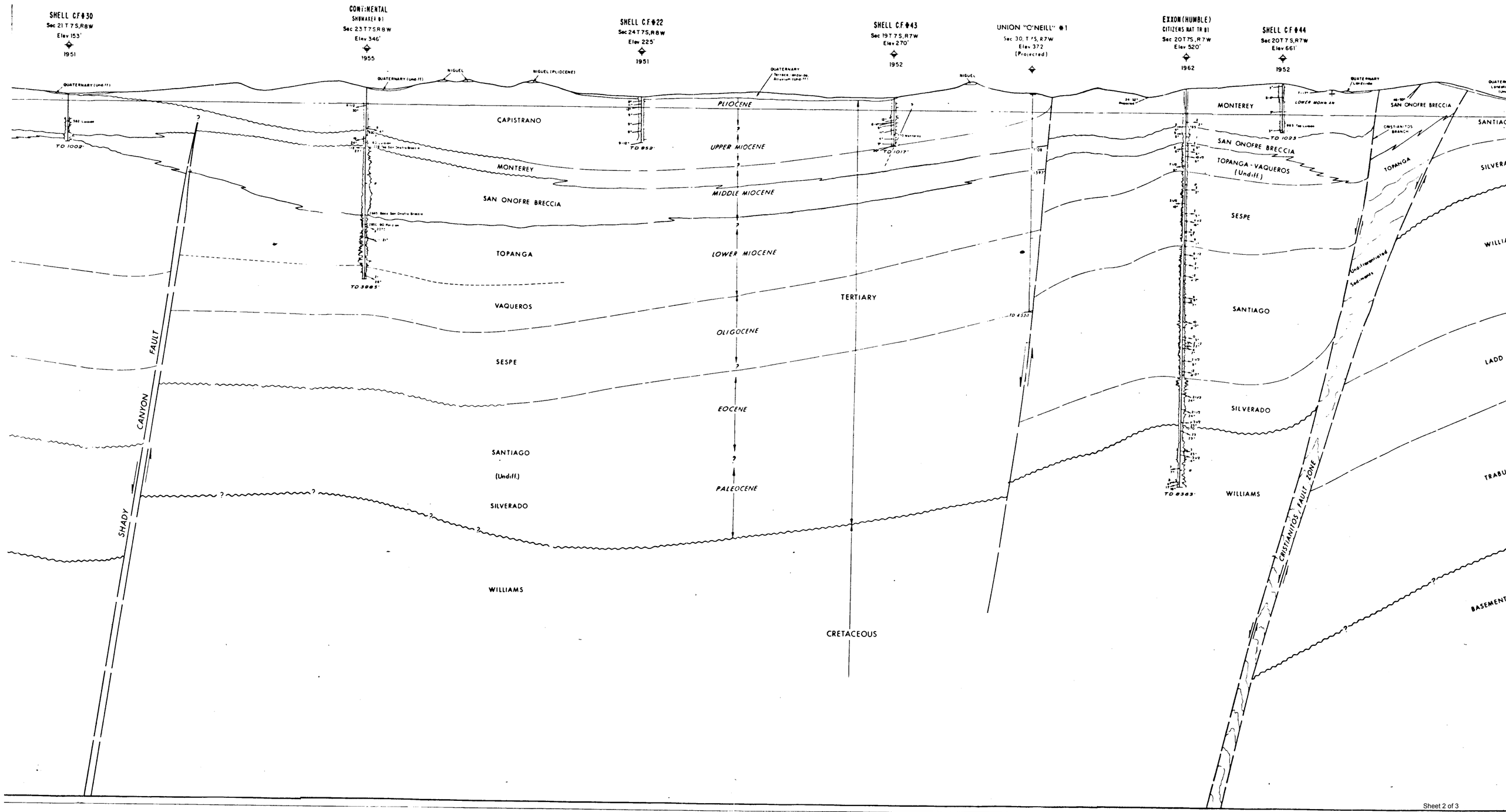
SANTIAGO
(Undiff)
SILVERADO
WILLIAMS
HOLZ SHALE
TERTIARY
CRETACEOUS
JURASSIC
BASEMENT COMPLEX
DIABASE FAULT DIKES
LAGUNA CANYON FAULT ZONE
QUATERNARY (Alluvium)
SAN ONOFRE BRECCIA
MIGUEL PLIOCENE
MONTEREY
1000 M
5000 FT
2000 M
3000 M
10,000 FT
4000 M
TD 9823'



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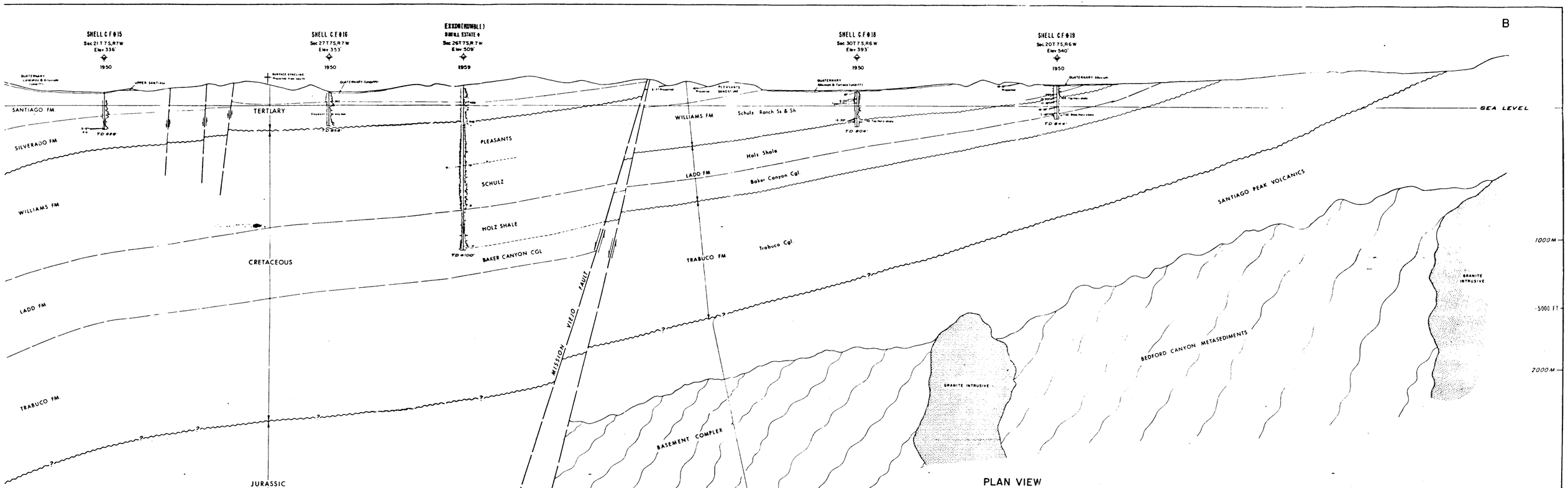

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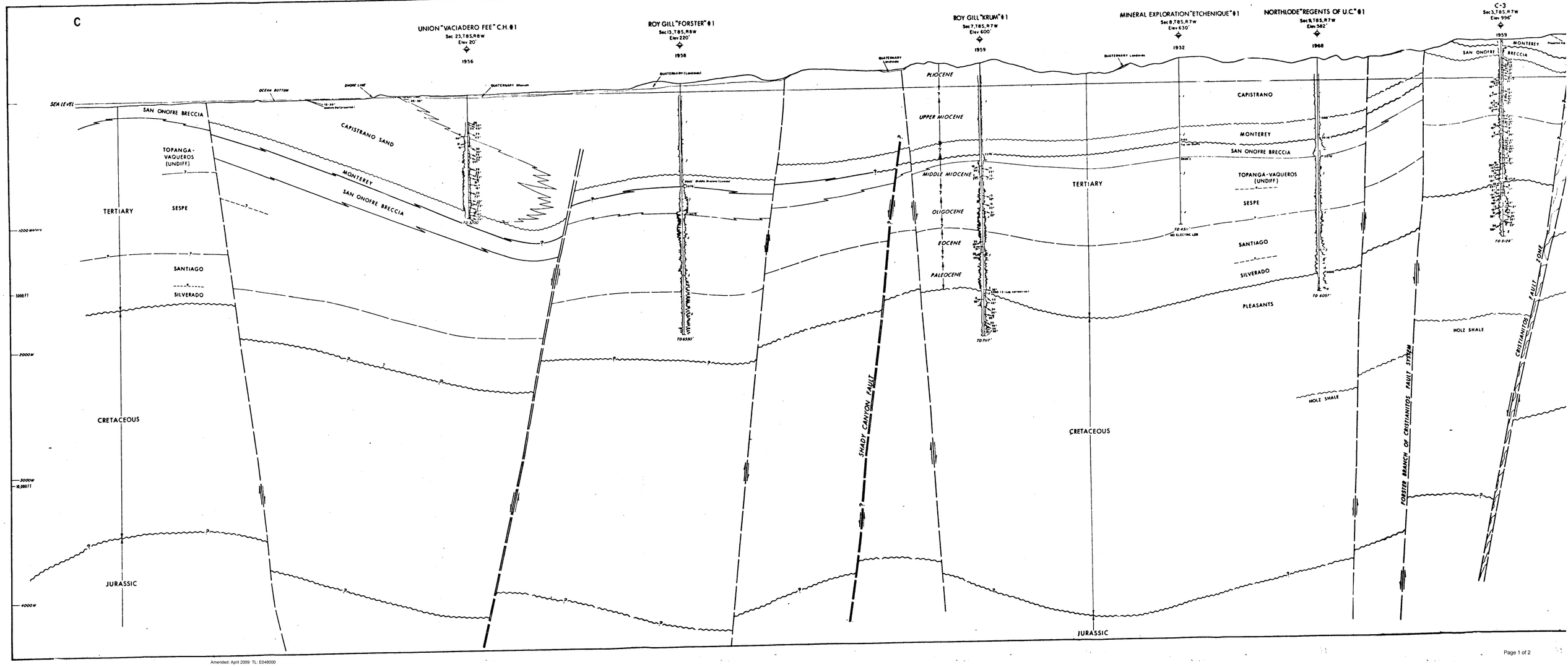
CAPISTRANO AREA
ORANGE COUNTY, CALIFORNIA
GEOLOGIC STRUCTURE SECTION
A - B

DATE JULY 17 REV DEC 1978



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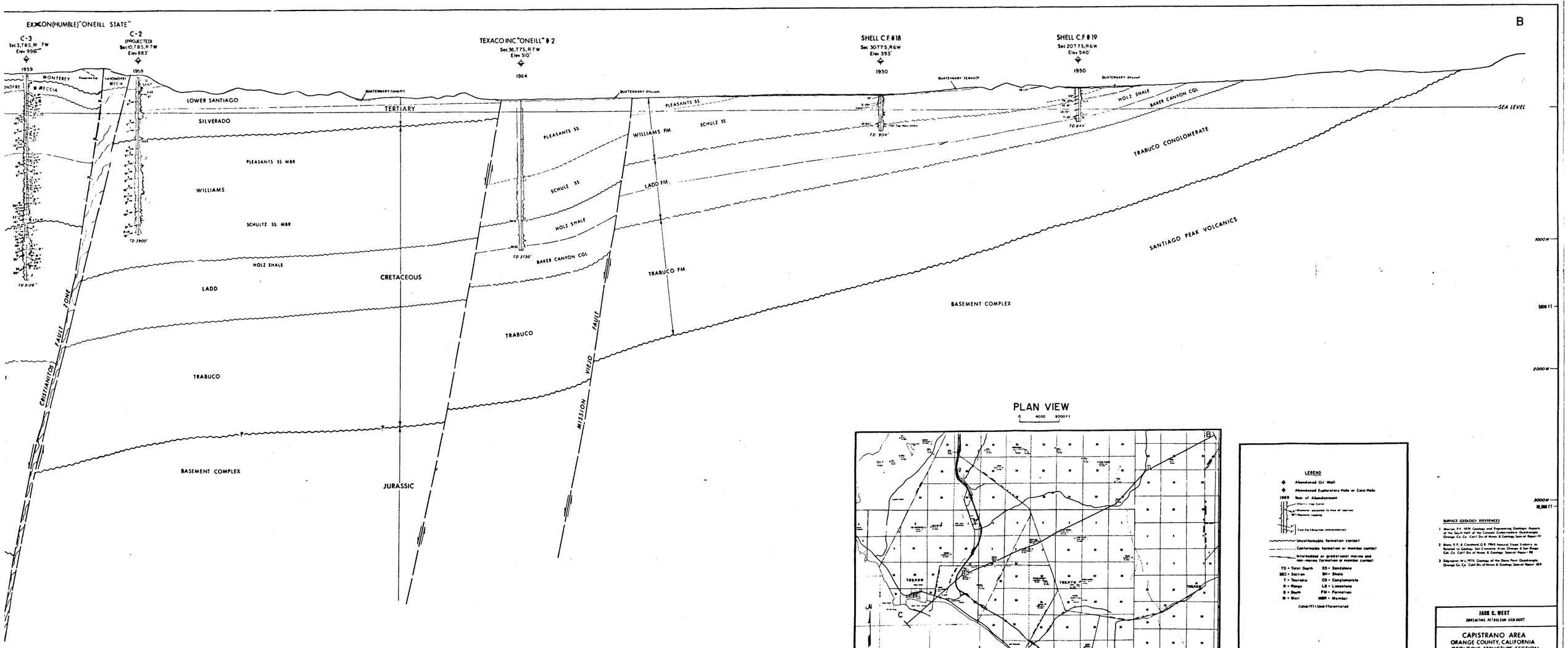
B
EXXON(HUMBLE)"ONEILL STATE"
C-3
Sec3,T8S,R 7W
Elev 996'
1959
C-2
(PROJECTED)
Sec10,T8S,R7W
Elev 883'
1959
TEXACO INC "ONEILL" # 2
Sec 36,T7S,R7W
Elev 310'
1964
SHELL C.F.# 18
Sec 30T7S,R6W
Elev 393'
1950
SHELL C.F.# 19
Sec 20T7S,R6W
Elev 540'
1950
MONTEREY
BRECCIA
LANDOFFRI BRECCIA
LOWER SANTIAGO
TERTIARY
SILVERADO
WILLIAMS
PLEASANTS SS MBR
SCHULTZ SS MBR
HOLZ SHALE
LADD
CRETACEOUS
TRABUCO
BASEMENT COMPLEX
JURASSIC
CRISTIANITOS FAULT ZONE
MISSION VIEJO FAULT
PLEASANTS SS
SCHULTZ SS
WILLIAMS FM.
LADD FM.
TRABUCO FM.
BAKER CANYON CGL
QUATERNARY (Undiff)
QUATERNARY Alluvium
QUATERNARY TERRACE
TRABUCO CONGLOMERATE
SANTIAGO PEAK VOLCANICS
SEA LEVEL
1000 M
5000 FT
2000 M
3000 M
10,000 FT
TD 9126'
TD 3900'
TD 3730'
TD 804'
TD 844'
PLAN VIEW
0 4000 8000 FT
T6S,R7W
T6S,R7W
T6S,R6W
T6S,R5W
N
C
B
LEGEND
Abandoned Oil Well
Abandoned Exploratory Hole or Core Hole
1969 Year of Abandonment
Electric Log Curve
Diamond projected to line of section
10" Diameter reading
Core Dia (diameter unmeasured)
Unconformable formation contact
Conformable formation or member contact
Interbedded or gradational marine and non-marine formation or member contact
TD = Total Depth
SEC = Section
T = Township
R = Range
S = South
W = West
SS = Sandstone
SH = Shale
CG = Conglomerate
LS = Limestone
FM = Formation
MBR = Member
(Undiff) = Undifferentiated
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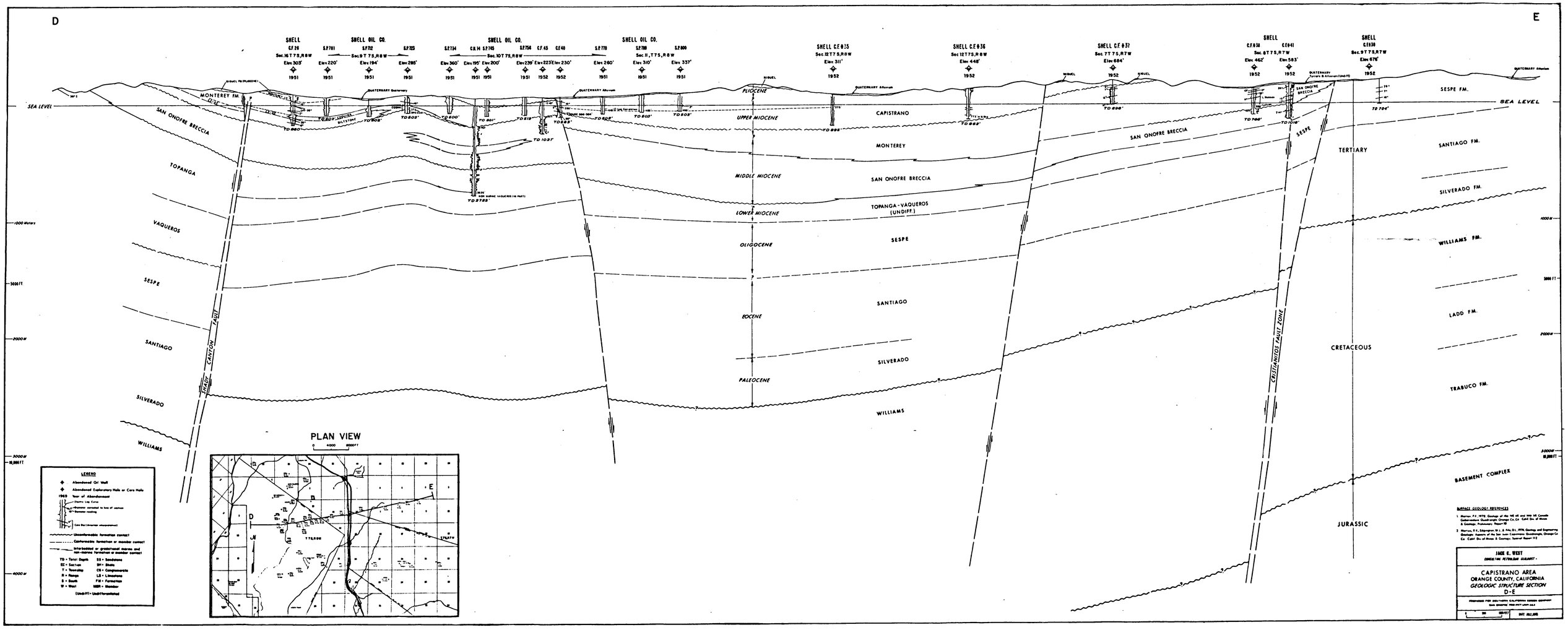
ORANGE COUNTY, CALIFORNIA
GEOLOGIC STRUCTURE SECTION
C-B
PREPARED FOR SOUTHERN CALIFORNIA GAS COMPANY
GAS STORAGE PROJECT-UNIT 3A5
1 500 1000 FEET
DATE JULY, 1975



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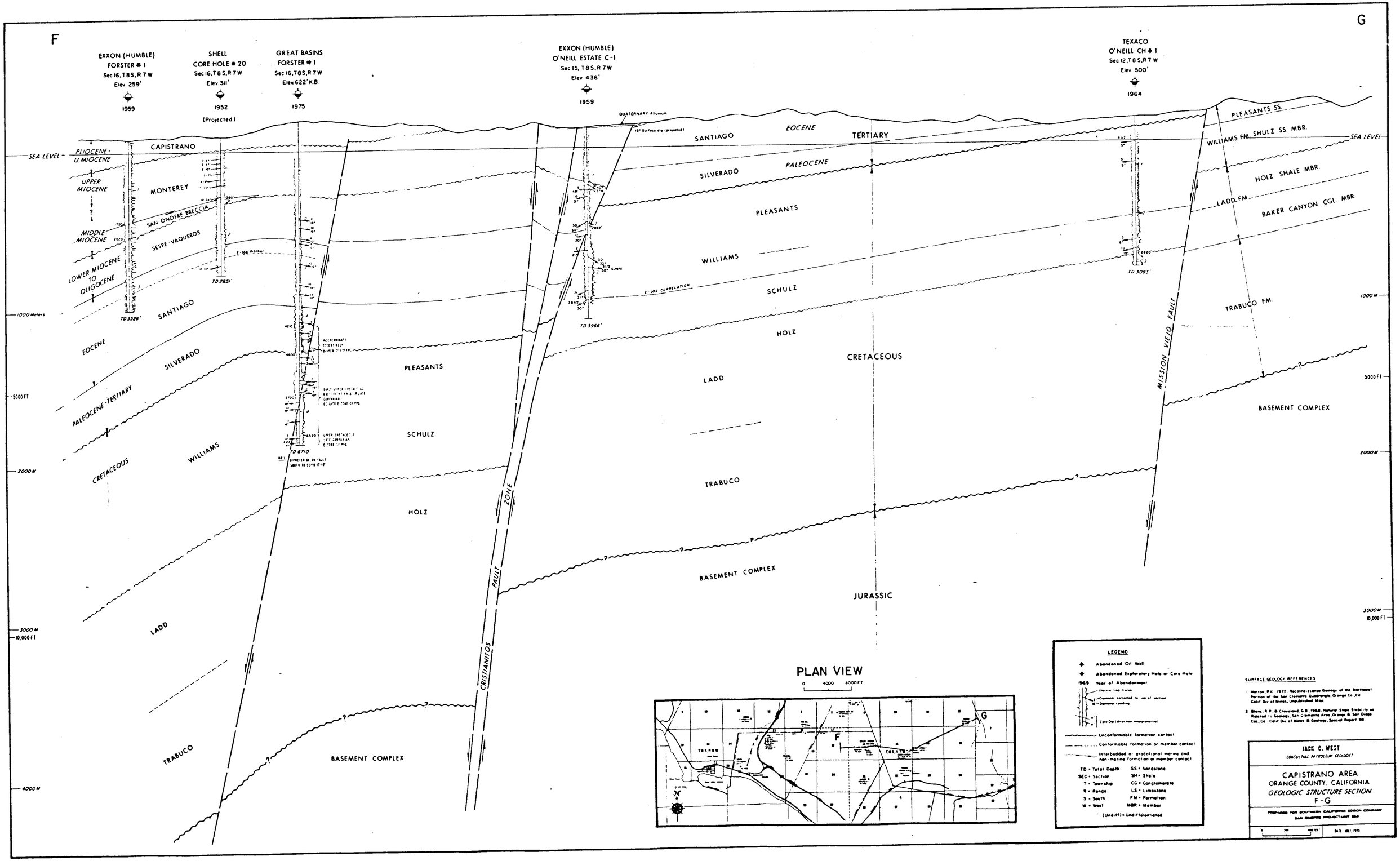

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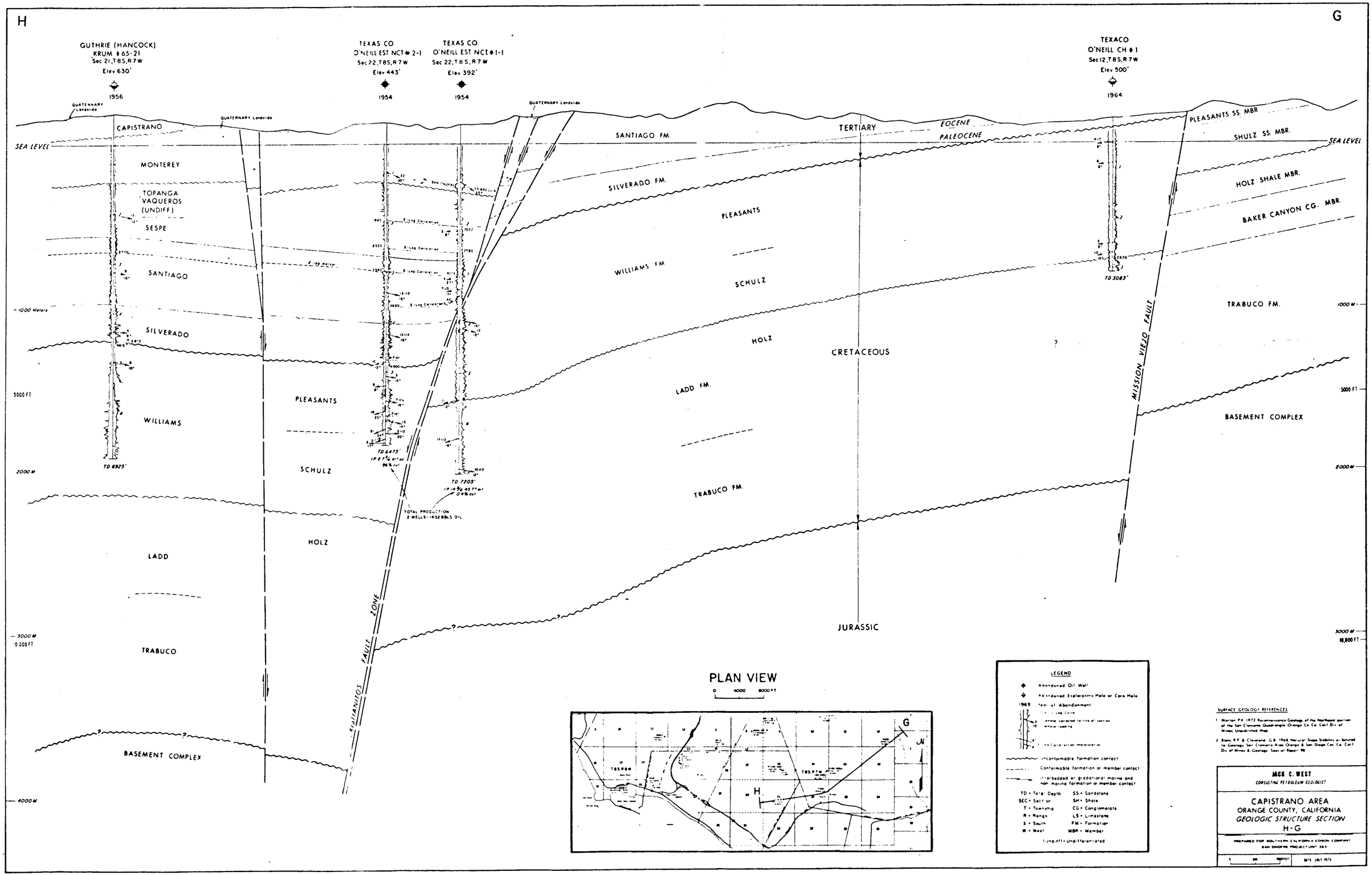

Amended: April 2009 TL: E048000

APPENDIX 2.5H

SUPPLEMENT TO THE GENERALIZED SUB-SURFACE GEOLOGICAL AND GEOPHYSICAL STUDY CAPISTRANO AREA ORANGE COUNTY, CALIFORNIA JANUARY 1979

Site File Copy

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SUPPLEMENT TO THE GENERALIZED SUB-SURFACE GEOLOGICAL AND GEOPHYSICAL STUDY

CAPISTRANO AREA
ORANGE COUNTY, CALIFORNIA

NOVEMBER 1975

JANUARY 1979

Amended: April 2009 TL: E048000

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ILLUSTRATIONS

Exhibit A-1 Monterey Countour Map

Exhibit B Cretaceous Contour Map-Revised

Structure Sections

1. A-B Revised
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3. D-E Revised
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6. K-L

Annotated Onshore Seismic Reflection Profiles

1. Line No. 152
2. Vibroseis Line No. 8
3. Line No. 147
4. Line No. 160

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INTRODUCTION

In partial response to NRC question 361.35 regarding the Capistrano Embayment, this report was prepared to supplement and revise my November 1975 report "Generalized Sub-Surface Geological and Geophysical Study, Capistrano Area, Orange County, California" (6). The present report centers on interpretations of the relationship between onshore and offshore geologic structure in the vicinity of the San Onofre Site. The illustrations included in this report are based upon newly acquired onshore seismic data, recent geologic surface mapping, formerly acquired offshore seismic data (2), and re-examination of all former surface geology and all available onshore and offshore well data. A general discussion of the illustrations follow in order to demonstrate the bases of interpretation, but in particular, this report addresses response to parts (c), (d), and (e) of the above NRC question.

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DISCUSSION OF ILLUSTRATIONS

EXHIBIT A-1 - Generalized Contours Near Top of Monterey Formation

General Comments

To present a comprehendable picture that reflects relatively late tectonics involving an area partly covered by water, a regional sub-surface contour map, based upon the most shallow and youngest information, is necessary.

After reviewing horizons within the Capistrano Embayment, the top of the Monterey Formation was selected as the best and most shallow horizon that could be mapped onshore and offshore. The contact of the top of the Monterey onshore outcrop, as mapped by surface workers (1) is shown on this exhibit. Microfaunal data indicate beds near this contact range in age from the lower part of the Upper Mohnian to Lower Mohnian. Sub-surface control on this horizon is provided by wells (microfaunal and electric log data) and seismic profiles. Where applicable, contouring of this horizon has been guided by folds observed in outcrop.

Western Geophysical's seismic "B" horizon (2), which is a "time map" was used to compile the offshore part of this map. Time "picks" on Western's map have been converted to depth using Western's velocities.

An area of "no data" exists between the most landward offshore seismic shot points and the shoreline. However, information from Mobil "San Clemente" No. 1 core hole, depth values from the seismic profiles, and extrapolition of onshore surface and well data to the offshore area--indicate that Western's seismic "B" horizon is approximately equivalent

to the top of the Monterey as contoured onshore. In my opinion, the accuracy of the onshore and offshore contours being equivalent is within 200 feet in elevation of each other.

A faulted anticline is interpreted to lie within the "no data" area mentioned above because of the southwest dip of seismic reflectors and the northeast dip of beds exposed along the shoreline. The dip of onshore beds decreases southeasterly along the shore and becomes nearly horizontal at the San Onofre Site. Quaternary deposits cover most of the older sediments, and surface dip data is quite sparse in the San Mateo Point--San Onofre area.

My structural interpretation of the offshore area is approximately the same as Western's with the exception of the fault near the Mobil "San Clemente" No. 1 core hole. Western, on their "time" map of the "B" horizon, has interpreted a fault southwest of the core hole. I agree that minor faulting may be present southwest of this hole. However, considering the age of the formation (Lower Mohnian) near the sea floor at this location together with the seismic data on Line No. 123, I interpret the main and significant fault to be northeast of the core hole as shown on this exhibit. Evidence of this fault lies between shot points 87 and 99 where:

1. An offset of reflections appear along the axis of a syncline, and
2. The bottom of the syncline has no reflections that flatten as they normally do.

In addition, spurious events (possibly reflected refractions), that could have been generated by this fault, occur between shot points 123 and 99 (see Structure Section K-L).

GENERAL STRUCTURE

From the El Toro area to San Juan Capistrano the overall structural setting of the Capistrano Embayment is a north-south synclinal basin interrupted by some west to northwest trending arches and some minor northwest trending faults. From San Juan Capistrano southward into the offshore area the synclinal basin becomes a series of northwest trending folds and faults nearly parallel to the shore line. Farther to the southeast and southwest the dominant structure is a more homoclinal, dipping southwestward. The South Coast Offshore fault zone comprises the major fault structure offshore.

FAULTING - Response to part (e) NRC question 361.35

Faults that more or less bound the Capistrano Embayment, or are exposed in outcrop outside the Embayment, are the Cristianitos fault on the east and the many faults of the San Joaquin Hills on the west. Faults cutting the Monterey Formation interior to the embayment are relatively rare, but several are shown in Exhibit A-1 generally south of San Juan Capistrano. The more important of these are discussed below. For discussion purposes three new fault names are introduced; these are, from east to west, the "Carr", "Vaciadero", and "Offshore Dana Point" faults.

Evidence for the "Carr" fault includes surface mapping (3), (4), and (5), and sub-surface contour spacing based on closest well control. The fault strikes north-northwest and dips steeply southwest. Its vertical displacement is down to the southwest (see Structure Section C-B). Its trace is obscured on the surface over one mile onshore from the shoreline. However, the shoreward extremities of seismic

lines No. 108 and No. 125 have evidence of faulting with "down-to-the-southwest" displacement. This displacement may possibly be the offshore extension of the "Carr" fault.

At one local area near the onshore surface trace of this fault a thin veneer of Niguel Formation has been mapped showing possible disturbance by this fault (4). The age of the Niguel Formation is probably Late Pliocene (5). Although we find that, in general, the Niguel Formation in the Capistrano Embayment is relatively undisturbed, this possible evidence suggests that the latest movement on the "Carr" fault may have been during the Late Pliocene.

Evidence for the "Vaciadero" fault consists of subsurface contouring based on local well control (dipmeter, paleontological, and electric log data). The fault plane is not exposed at the surface and is, therefore, believed to be older than the "Carr" fault. Its apparent direction of displacement, although larger, is the same as the "Carr" (see Structure Section C-B). Evidence of its strike is lacking. Its strike has been assumed to be similar to the "Carr" fault.

Evidence for the "Offshore Dana Point" fault consists of the low structural position of the seismic "B" horizon (approximate equivalent to the top of the Monterey) near the intersection of seismic lines No. 110 and No. 129 compared to the older surface rocks (San Onofre Breccia) cropping out at Dana Point. This suggests considerable vertical movement, down to the south (see Structure Section C-B). Evidence of "offset" of seismic reflections near the intersection of

line No. 110 and line No. 127 (SP 40), where a down-to-the-southwest displacement is indicated, is interpreted as the southeast extension of the "Offshore Dana Point" fault. If this fault is part of the Laguna Canyon fault zone onshore, as suggested by its alignment, and the two faults are contemporaneous, then the last movement of the "Offshore Dana Point" fault is probably no later than Upper Miocene.

The Dana Point fault has been mapped at the ground surface (1). Its dominant displacement appears to be vertical and down to the northeast, resulting in a horst block in the Dana Point area. Latest movement on this fault was also probably during the Upper Miocene.

The South Coast Offshore fault has been interpreted as a zone of faulting including displacements that are down to the southwest and down to the northeast. In occassional areas possible lateral displacement has been interpreted. Horst blocks within the fault zone have resulted from this variable direction of displacement. The fault zone also varies considerably in width (see Western's Horizon C map (2)). In addition, different age of movement has been involved since only older beds are disturbed in certain areas along the fault zone (see Structure Sections C-B, H-G, and I-J).

Only that part of the South Coast Offshore fault zone nearest the shore is seen at the seismic "B" horizon (near top Monterey). Evidence for this part of the fault zone is seen on seismic line No. 127, where labeled the "South Coast Offshore Fault", and on alignment toward the southeast, on seismic lines Nos. W-10, 145, WS 70-18, and 123.

However, the fault does not continuously displace this horizon although older beds may be disturbed. For example, the fault does not displace seismic horizon "B" on seismic lines Nos. 129 or 125. Some lateral movement (possibly 2500 feet) is suggested by offset contours near the intersection of seismic lines Nos. 145 and WS 70-18.

The Cristianitos fault appears to die out southerly at Monterey depth. However, along the projection of the Cristianitos fault, evidence of faulting of older beds can be observed on seismic line No. 106 (see Structure Section K-L).

Considerable minor faulting based on surface mapping (1) is shown in the central part of T8S, R7W, where Monterey crops out. Due to the lack of significant displacement of the top of the Monterey contact in outcrop, these faults are considered minor. At Monterey depth at more basinward positions the contours accordingly show minor to no displacement on these faults. Since the Niguel Formation, located farther north and west within the Capistrano Embayment has had relatively little fault disturbance, it is believed that movement on these faults in this area probably ceased during the Late Pliocene.

EXHIBIT B - Contours on Top of Cretaceous (Revised)

This exhibit, when formerly submitted under reference (6), was intended basically to demonstrate the Cristianitos fault at Cretaceous depth and its relationship to the January 1975 earthquakes.

The revised map, insofar as available data permits,

represents a better and more accurate regional interpretation of the area at Cretaceous depth because of newly acquired data and further study of faults in conjunction with the construction of the Monterey map, Exhibit A-1.

Most of the revisions of this map are confined to the southwestern portion from the Dana Point--San Clemente area northward into the northern part of T7S, R8W.

Newly acquired seismic data, specifically line No. 147 (discussed further below), contains information that supports the presence of a syncline, an anticline, and possibly, the Shady Canyon fault. The location of this line is plotted on this map and the interpretation of the structure at Cretaceous depth has been revised as shown by the contours.

The position of the Shady Canyon fault has been revised to conform with its interpreted location on line No. 147; that is, it is now shown about 1,000 feet northeast from its former location in the vicinity of line No. 147, but otherwise remains as shown on the original map.

The possible extension of the Shady Canyon fault southeast from the location of line No. 147 is based on Cretaceous well points to the east and estimates of Cretaceous depths west of the fault. More specifically, the Cretaceous depth, -5,360 feet at Roy Gill Krum No. 1, Section 7, T8S, R7W, is regionally fairly shallow. There are no deep holes southeast of the Shady Canyon fault except Roy Gill Forster No. 1, Section 13, T8S, R8W. This hole did not reach the Cretaceous, but it is estimated at -7,000 feet. I interpret this large difference of Cretaceous elevations between the above holes to be due to faulting--partly by the "Carr" fault (discussed above) and partly by the Shady Canyon fault (see Structure Section C-B).

The direction and length of the "Carr" and "Vaciadero" faults at Cretaceous depth have been changed to conform with the Monterey map where their displacement, direction, and length have been discussed above. These faults were not named in the original 1975 report but they can be identified on the original map by referring to Structure Section C-B.

An interpretation at Cretaceous depth of the Laguna Canyon and Temple Hill faults, plus some additional minor faulting have been added in the San Joaquin Hills area because they have been shown by former workers (1) and (4). They probably disturb the Cretaceous, and they show the direction of faulting in this area.

An interpretation is also shown at Cretaceous depth of the offshore anticline (near the shore line) cut by the "Dana Point", "Vaciadero", and "Carr" faults, (discussed above at Monterey depth).

Further Cretaceous mapping offshore was not attempted since the horizon would fall below the "Acoustic Basement" mapped by Western Geophysical (2). Seismic data is undiagnostic below this horizon offshore.

STRUCTURE SECTIONS

Sections A-B, D-E, C-B, and H-G accompanied the 1975 report (6) but they have been corrected to reflect revisions made on Exhibit B and to conform with the Monterey contours and faults shown on Exhibit A-1. Sections C-B and H-G have been extended seaward along seismic lines (2) and two additional sections, I-J and K-L have been prepared along

seismic lines to further demonstrate the geologic interpretation and relationship between the onshore and offshore in the vicinity of the San Onofre Site. Seismic horizons "B" and "C", mapped by Western Geophysical (2), have been converted to depth on these sections. The location of the South Coast Offshore fault zone, discussed above, is noted on the offshore portion of each section.

Section C-B shows the offshore anticline originating with a horst block (projected from Dana Point) and with considerable relief. Also, note that Section C-B shows the "B" horizon undisturbed by the South Coast Offshore fault zone. However, this horizon is shown offset by the landward edge of this fault zone on Section H-G.

Structure Section I-J was selected to fall directly under the San Onofre Site where a shallow hole bottomed at 989' in San Mateo Sands that appear in age to be equivalent to the lower part of the Capistrano. The offshore portion of this section is tied to seismic line No. WS 70-18, which illustrates the South Coast Offshore fault zone that forms a large horst block. The interpretation is partially supported by two shallow core holes, No. 92 and No. 93. These holes were drilled in 1968 by an oil group that was gathering data in preparation for offshore sales. These holes support the presence of a thin veneer of Quaternary and Uppermost Tertiary sediment in the offshore area. Based on these data, a thin, shallow interval of similar age sediments is presumed to be present also in the offshore portion of Section H-G and Section K-L.

Structure Section K-L is supported by the Mobil "San Clemente" No. 1 offshore core hole, total depth 6,130 feet,

seismic offshore data, and onshore surface geology. For reasons given under general comments, Exhibit A-1, the location of the fault immediately shoreward of the above core hole differs from Western Geophysical's interpretation (2). This fault is the landward edge of the South Coast Offshore fault zone.

Annotated Onshore Seismic Reflection Profiles

The following profiles (lines) have been annotated with geology and are discussed below in response to part (c), NRC question 361.35. The line locations are shown on Exhibits A-1 and B.

In general, these profiles have some value in relation to the dip of shallow beds and they have been used to support contours on Exhibit A-1. However, seismic reflections at Cretaceous depth are very poor and have less value. Line 147, the eastern part of line 152, and the Mobil vibroseis lines have partially aided the construction of the Cretaceous map, Exhibit B.

Seismic Line No. 152

The original records (1964), even with modern processing (1975), have resulted in very poor data to interpret. The eastward one-half of this line shows reflections with westward dip. The westward one-half has unreliable data at Cretaceous depth, however, some indication of minor folding at shallow depths occurs between shot points 21 and 28. Evidence of faulting is very weak and, without the benefit of surface geology and well data, the fault interpretation on the Cristianitos fault zone and branch faults

as shown on the annotated section could not be made. Only with the knowledge of the fault locations at the ground surface can the fault planes be extended in depth in the manner shown based upon the appearance of reflections. The dips shown on the fault planes are partly influenced by regional geologic evidence of westward dipping "down-to-the-west" movement on the Cristianitos and associated branch faults. Therefore, the seismic line alone, with no geologic supplementary data, has very little value in determining the age and capability of faults. It does, in general, help to confirm the west dip of the sediments east of the Cristianitos fault.

Vibroseis Line No. 8

This seismic section (1971) has slightly more useful data than N-152. Some evidence of faulting exists which can be interpreted without the aid of surface and sub-surface supplementary geologic information. The best fault evidence consists of the termination and apparent offset of reflections between shot points No. 190 and No. 200, which coincides with a surface fault that is a branch of the Mission Viejo fault. The Mission Viejo fault, however, which is a large fault, has little evidence of offset in the reflections. With the aid of surface geology and well data that falls on this line, a fairly good geologic interpretation is shown on this annotated seismic section. However, in respect to defining and evaluating the age and capability of faults, this seismic line alone--without surface and sub-surface geology has little value. Geologic structure section C-B, which falls partly on this seismic line, suggests that the Mission Viejo Fault and its branches

occurred sometime after the Lower Tertiary. With the surface geology, however, the reflections on vibroseis line No. 8 aid in determining the amount of fault displacement.

Seismic Line No. 147

This line was shot in 1954 and reprocessed in 1964 by Standard Oil. More useable data is present on this line than any other onshore seismic line examined in this area. Still the reflections are comparatively of low quality, but they do define an anticline and a syncline. Faulting is indicated where shown as the possible extension of the Shady Canyon Fault that is mapped on the surface in the San Joaquin Hills area to the northwest. A predominance of northward dipping reflectors (1.5 to 2.5 seconds) is shown on the section--mainly on the southern half. These data probably do not represent geology in the plane of the section. They are believed to be refractions from a source away from the plane of the section--possibly from faults located to the west on the eastern slope of the San Joaquin Hills. The section is supplemented by well data shown annotated along with an interpretation of the geology. Fault evidence is not strong, but the reflections indicate disturbance in the area where the Shady Canyon Fault is interpreted as possibly present. In this case the seismic data suggest that the latest movement on the Shady Canyon Fault was just prior to the deposition of the Monterey, probably during the Middle Miocene.

Seismic Line No. 160

This line was recently acquired from Standard Oil along with line No. 147. It was also shot in 1954 and reprocessed

in 1964 by Standard. Reflections on this line are very poor and there does not appear to be any substantial evidence to support faulting. Some minor folding is suggested in the more shallow beds as shown by the annotated geology. The poor data does partly support the general geology where the line is located on the contour maps--Exhibits A-1 and B.

Well Data

Well data comprise all available information pertaining to logs of "borings" requested under part (d) of NRC question 361.35. In August of 1977 all of the well data was compiled and annotated on electric logs of all holes that had run electric logs. The annotations showed in briefed form all significant data such as dipmeter, cores, sidewalls, tops of geologic horizons, fault interpretations, and paleontology. Where electric logs were not run the history and drillers log were compiled. All of these data were forwarded to the NRC in December 1977.

CONCLUSION

In addition to responses to specific portions of NRC question 361.35, this report includes an illustration (Exhibit A-1) of the most extensive, shallow, and mappable sub-surface horizon onshore and offshore in the San Onofre region. The interpretations shown on this and the additional illustrations suggest that the major tectonic activity within ten miles of the site took place prior to the termination of the Pliocene epoch, possibly two million years before present; and since that time the area has been tectonically quiet--with the exception of the South Coast Offshore fault zone along which some movement probably occurred in the Late Pleistocene. Data that I have examined reveal no additional faults of this or younger age within about five miles of the San Onofre site.

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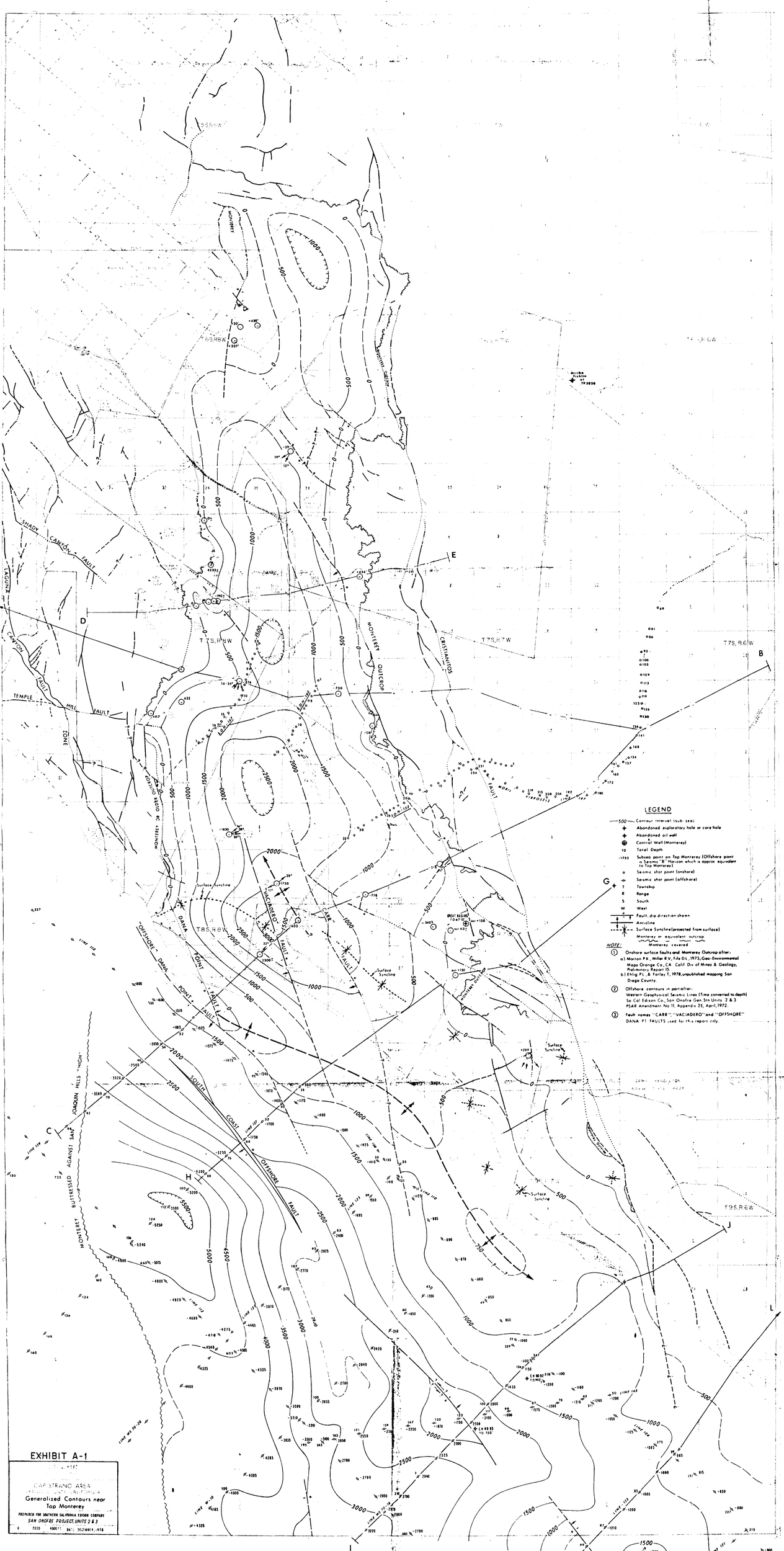
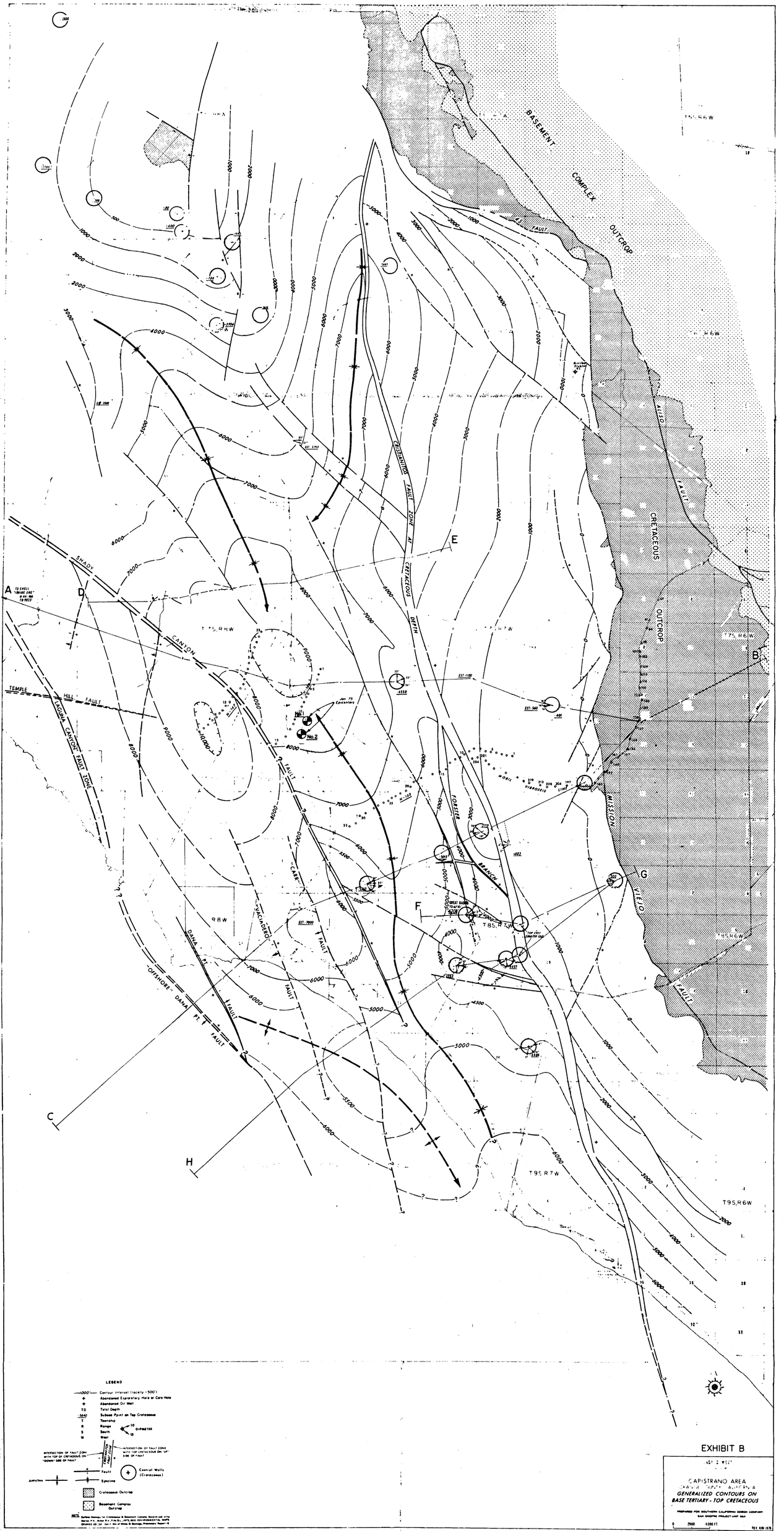
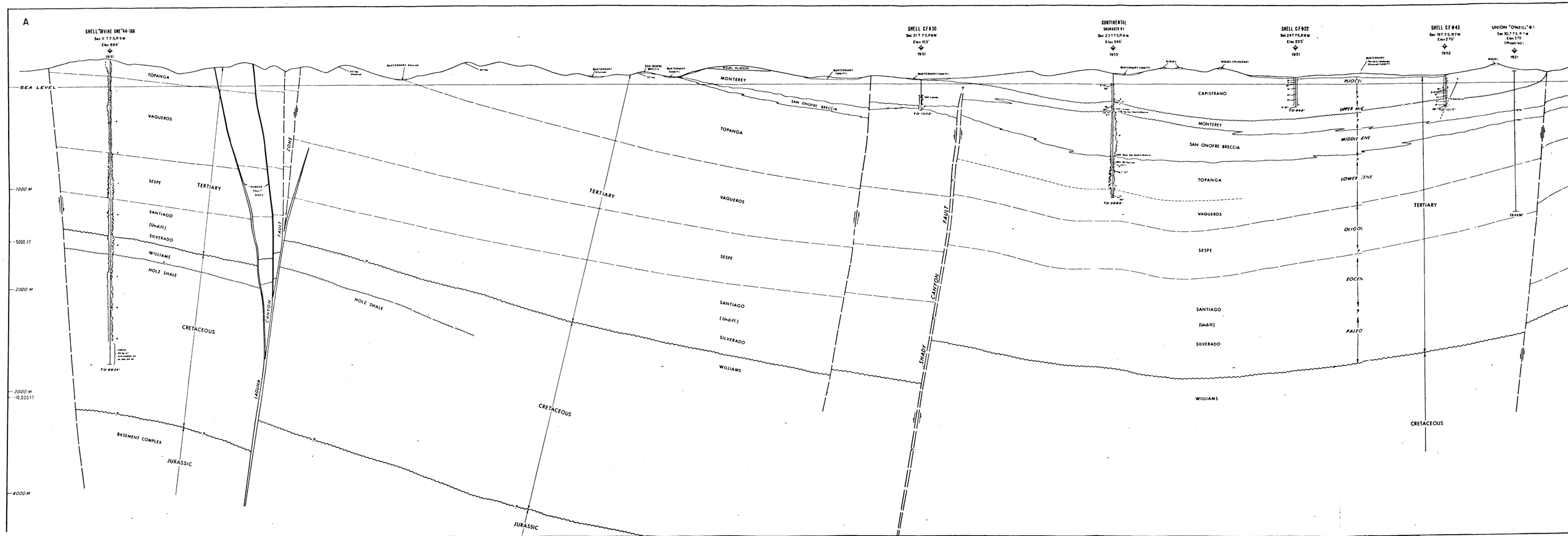
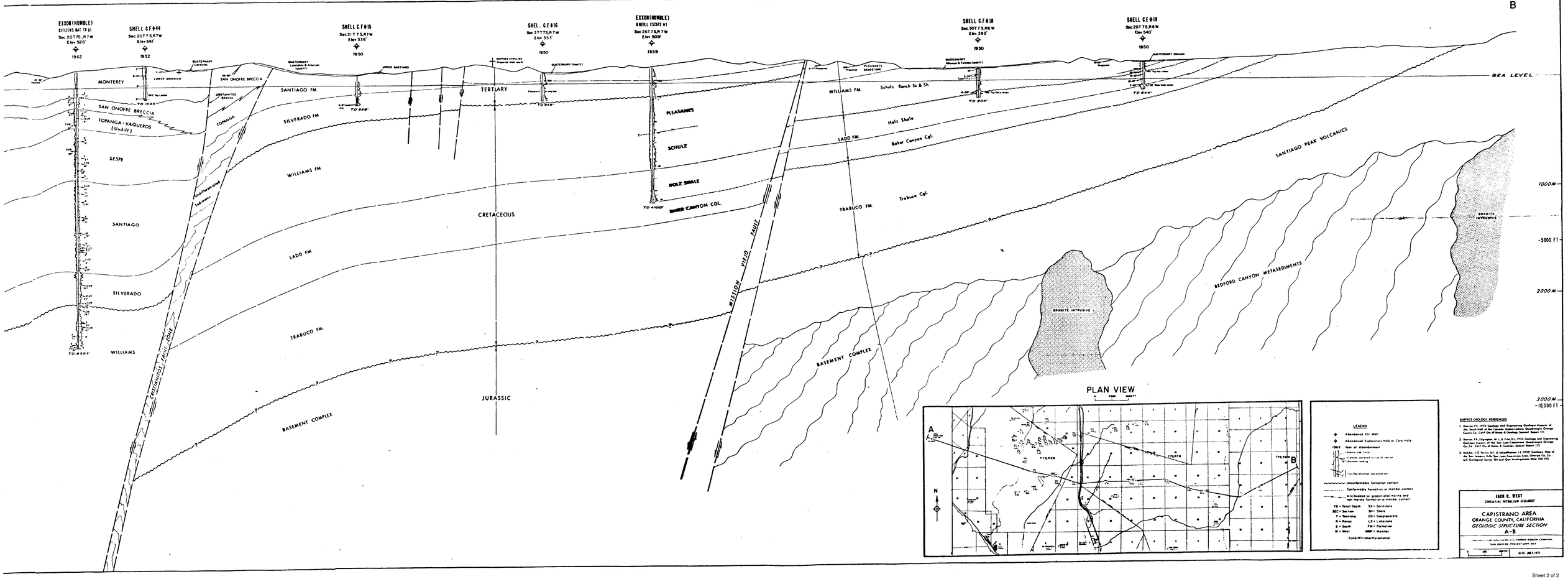
7. EHLIG, P.L. FARLEY, T. Geology Map Adjacent to San Onofre Nuclear Generating Station--Unpublished 1978


LEGEND
500 Contour Interval (sub sea)
Abandoned exploratory hole or core hole
Abandoned oil well
Control Well (Monterey)
TD Total Depth
-1755 Subsea point on Top Monterey (Offshore point is Seismic "B" Horizon which is approx equivalent to Top Monterey)
Seismic shot point (onshore)
Seismic shot point (offshore)
T Township
R Range
S South
W West
Fault, dip direction shown
Anticline
Surface Syncline (projected from surface)
Monterey or equivalent outcrop
Monterey covered
NOTE:
① Onshore surface faults and Monterey Outcrop after:
a) Morton P.K., Miller R.V., Fife D.L., 1973, Geo-Environmental Maps Orange Co., CA Calif. Div. of Mines & Geology, Preliminary Report 15.
b) Ehlig P.L. & Forler T, 1978, unpublished mapping San Diego County.
② Offshore contours in part after:
Western Geophysical Seismic Lines (Time converted to depth)
So Cal Edison Co., San Onofre Gen Stn Units 2 & 3
PSAR Amendment No. 11, Appendix 2E, April, 1972.
③ Fault names "CARR", "VACIADERO" and "OFFSHORE" DANA PT. FAULTS used for this report only.
EXHIBIT A-1
CAPISTRANO AREA
Generalized Contours near Top Monterey
PREPARED FOR SOUTHERN CALIFORNIA EDISON COMPANY
SAN ONOFRE PROJECT, UNITS 2 & 3
DATE: DECEMBER 4, 1978
SHADY CANYON FAULT
TEMPLE HILL FAULT
MONTEREY OUTCROP
CRISTIANITOS
VACIADERO FAULT
DANA POINT FAULT
"OFFSHORE" DANA POINT FAULTS
SOUTH COAST OFFSHORE FAULT
MONTEREY BUTTRESSED AGAINST SAN JOAQUIN HILLS "HIGH"
T7S,R8W
T7S,R7W
T7S,R6W
T8S,R8W
T8S,R7W
T9S,R6W
Surface Syncline



Amended April 2000 TL 8048000


A
SHELL "IRVINE ONE" 44-166
Sec 11 T 7 S, R 9 W
Elev 884'
1951
SHELL CF #30
Sec 21 T 7 S, R 8 W
Elev 153'
1951
CONTINENTAL
SHUMAKER #1
Sec 23 T 7 S, R 8 W
Elev 346'
1955
SHELL CF #22
Sec 24 T 7 S, R 8 W
Elev 225'
1951
SHELL CF #43
Sec 19 T 7 S, R 7 W
Elev 270'
1952
UNION "O'NEILL" #1
Sec 32 T 7 S, R 7 W
Elev 372
(Projected)
1921
SEA LEVEL
1000 M
5000 FT
2000 M
3000 M
10,000 FT
4000 M
TOPANGA
VAQUEROS
SESPE
SANTIAGO
(Undiff.)
SILVERADO
WILLIAMS
HOLZ SHALE
TERTIARY
CRETACEOUS
BASEMENT COMPLEX
JURASSIC
LAGUNA CANYON FAULT ZONE
MONTEREY
SAN ONOFRE BRECCIA
SHADY CANYON FAULT
CAPISTRANO
PLIOCENE
UPPER MIOCENE
MIDDLE MIOCENE
LOWER MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
TO 1002'
TO 3988'
TO 948'
TO 1013'
TD 4330'



Amended: April 2009 TL: E048000

C

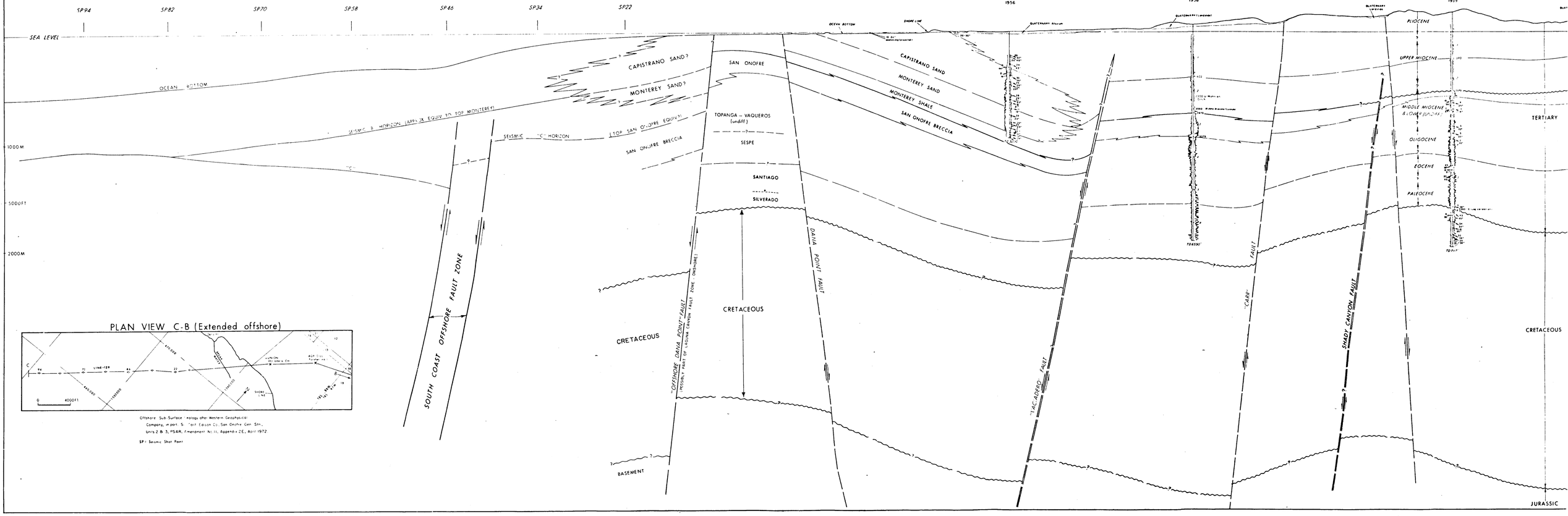
LANDWARD PORTION

WESTERN GEOPHYSICAL SEISMIC LINE — 129

UNION "VACIADERO FEE" C.H. #1
Sec. 23, T8S, R8W
Elev. 20'
1956

ROY GILL "FORSTER" #1
Sec. 13, T8S, R8W
Elev. 220'
1958

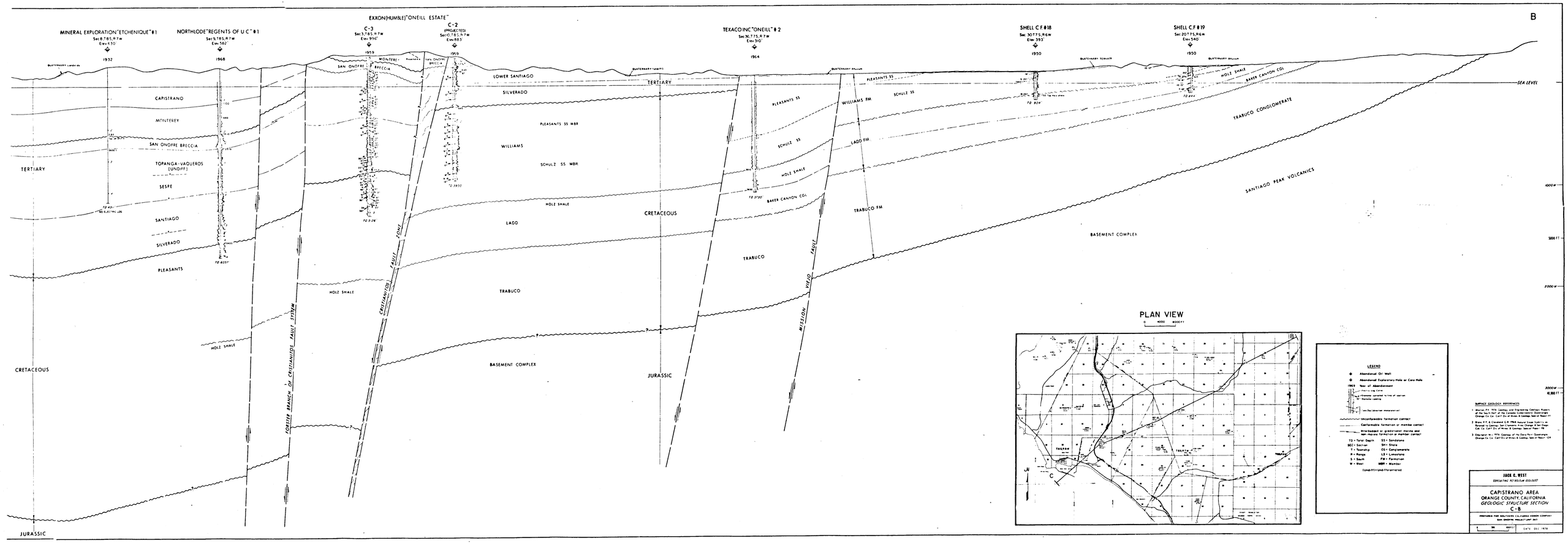
ROY GILL "KRUM" #1
Sec. 7, T8S, R7W
Elev. 600'
1959



PLAN VIEW C-B (Extended offshore)

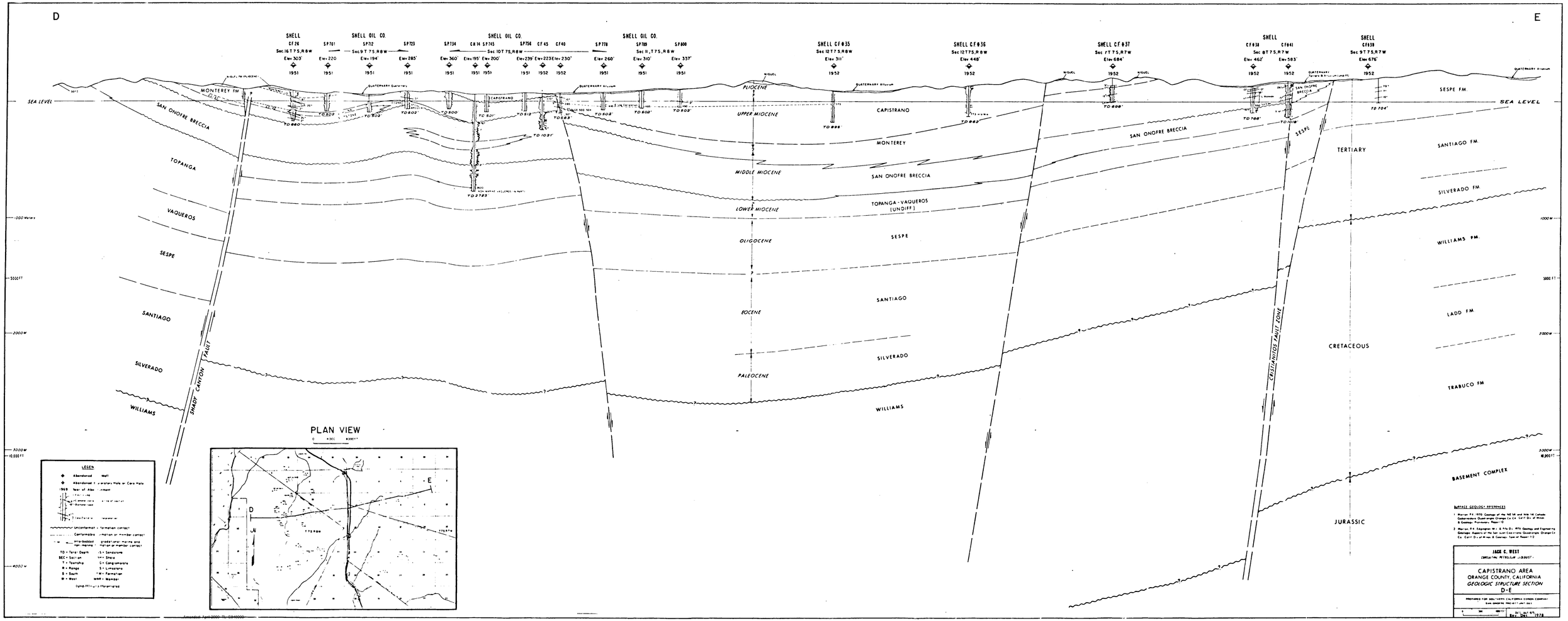
Offshore Sub-Surface Geology after Western Geophysical Company, in part S. Calif Edison Co. San Onofre Gen Stn., Units 2 & 3, PSAR, Amendment No.11, Appendix 2E, April 1972

SP: Seismic Shot Point



Sheet 2 of 2

Amended: April 2009 TL: E048000



Amended April 2000 TL-0040000

H

LANDWARD PORTION
WESTERN GEOPHYSICAL SEISMIC LINE — 127
(migrated depth section)

G

SP88 SP76 SP64 SP52 SP40 SP28

SEA LEVEL

OFFSHORE — ONSHORE

SURFACE DIP (Projected)

SURFACE STRUCTURE

GUTHRIE (HANCOCK) KRUM # 65-21 Sec 21,T6S,R7W Elev 630' 1956

TEXAS CO O'NEIL EST NCT # 2-1 Sec 22,T6S,R7W Elev 443' 1954

TEXAS CO O'NEIL EST NCT # 1-1 Sec 22,T6S,R7W Elev 392' 1954

TEXACO O'NEIL CH # 1 Sec 12,T6S,R7W Elev 500' 1964

OCEAN BOTTOM

RECENT — PLEISTOCENE — PLIOCENE

CAPISTRANO

SEISMIC HORIZON "B"

(APPROX EQUIV TOP MONTEREY) "B"

"C" (APPROX EQUIV TO TOP SAN ONOFRE)

UPPER MIOCENE

MONTEREY

SEISMIC HORIZON "C"

MIDDLE MIOCENE

SAN ONOFRE BRECCIA

CRETACEOUS ?

SOUTH COAST OFFSHORE FAULT ZONE

OFFSHORE DANA POINT FAULT

"LAGUNA" FAULT

"CARR FAULT"

"DONER CANYON FAULT"

SAN ONOFRE BRECCIA

CAPISTRANO

MONTEREY

TOPANGA VAQUEROS (UNDIFF.)

SESPE

SANTIAGO

SILVERADO

WILLIAMS

LADD

TRABUCO

BASEMENT COMPLEX

TERTIARY

CRETACEOUS

PLEASANTS

SCHULZ

HOLZ

CRYSTALLINE FAULT ZONE

TOTAL PROJECTION OF WELLS WITHIN 1 MILE

SANTIAGO FM.

SILVERADO FM.

WILLIAMS FM.

PLEASANTS

SCHULZ

HOLZ

LADD FM.

TRABUCO FM.

TERTIARY

EOCENE

PALEOCENE

CRETACEOUS

JURASSIC

PLEASANTS SS MBR

SHULZ SS MBR

HOLZ SHALE MBR

BAKER CANYON CG. MBR

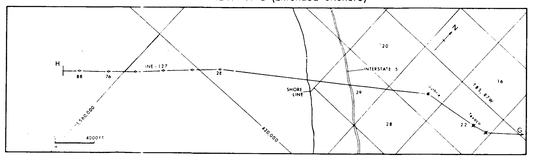
TRABUCO FM.

BASEMENT COMPLEX

MISSION VIEJO FAULT

1000M 3000FT 2000M 6000FT 3000M 10,000FT

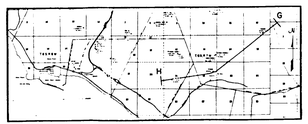
PLAN VIEW H-G (Extended offshore)



Offshore Sub-Surface Geology after Western Geophysical Company, in part. So. Calif. Edison Co., San Onofre Gen. Stn. Units 2 & 3, PSAR, Amendment No. 11, Appendix 2E, April 1972

SF - Seismic Shot Point

PLAN VIEW



LEGEND

- Abandoned Oil Well
- Abandoned Exploration Hole or Core Hole
- 1963 Year of Abandonment
- Fault, dashed where inferred
- Fault, buried
- Fault, dashed where inferred
- Unconformable Formation Contact
- Conformable Formation or Member Contact
- Approximate or gradational mapping and non-marine formation or member contact
- TQ - Tertiary Quaternary
- MZ - Mesozoic
- SC - Santiago
- SH - Shale
- Ss - Sandstone
- Cg - Conglomerate
- P - Pleasants
- Lm - Limestone
- S - Schulz
- F - Formation
- H - Holz
- MBR - Member
- Line Interpreted

SUPPORT GEOLOGIC REFERENCES

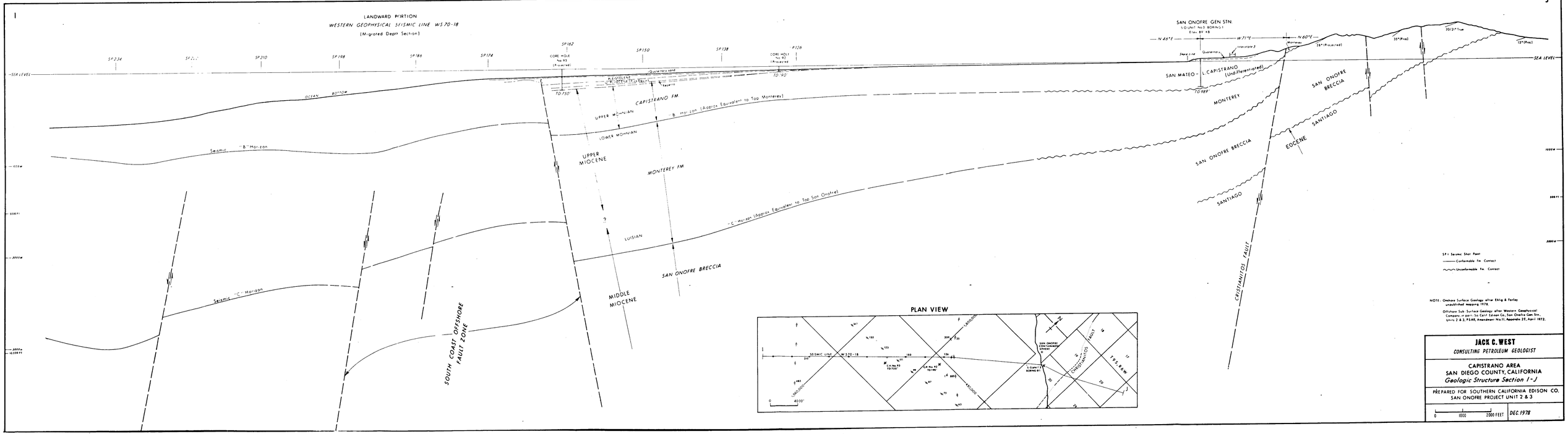
1. Bishop, R.E. 1972 Reconnaissance Geology of the Northeast part of the San Juan Capistrano Quadrangle Orange Co. Calif. Ms. of Geology Thesis Calif. State Univ. Fullerton.
2. Bishop, R.E. & Campbell, J.A. 1974 Reconnaissance Geologic Map of the Capistrano Quadrangle Orange Co. Calif. Ms. of Geology Thesis Calif. State Univ. Fullerton & Geologic Table of Texas Inc.

REX E. WEST
(Calif. Reg. PG 1133 Exp. 12-31-76)

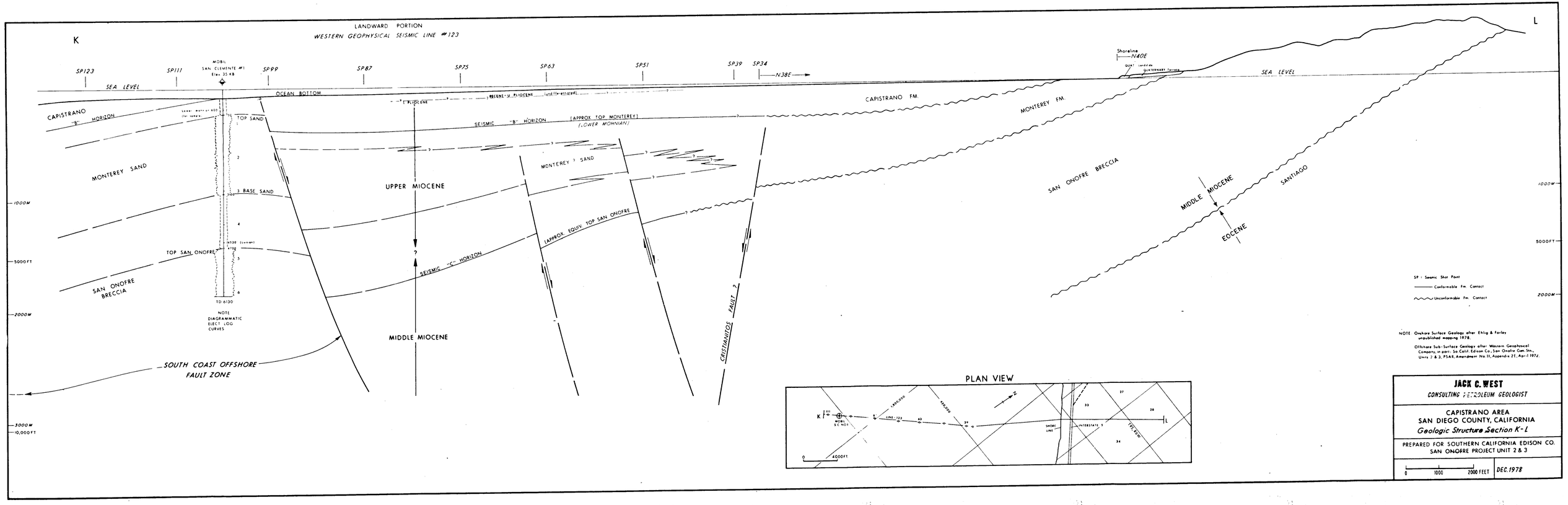
CAPISTRANO AREA
ORANGE COUNTY, CALIFORNIA
GEOLOGIC STRUCTURE SECTION
H-G

PREPARED FOR: MOBIL OIL CORP. & CALIFORNIA EASTERN COMPANY
PLAN DRAFTED: FEB. 27 1974 — REV. DEC. 1974

Amended April 2009 TL 8048000



Amended: April 2009 TL: E048000



Amended: April 2009 TL: E048000

LINE: N 152
S.P. : 1-31

SOUTHWEST

SOUTHERN CALIFORNIA EDISON COMPANY
LINE N 152
PARTY 32
SAMPLE RATE .4 MS
PROCESS DIGITAL 100% RECORDS
DATUM PLANE SEA LEVEL
WESTERN GEOPHYSICAL

RECORDING
AMPLIFIER
GAIN FAST
DATE SEPTEMBER 1954
SYSTEM DYNAMITE
FILTER 25-41 50%
SPREAD 800'@-800'
S.P. INT 800' (VARIABLE)
SHP INT 50' (VARIABLE)
PHONES / SHP 3

PROCESSING
1 TRANSCRIPTION
2 REFORMAT
3 DECONVOLUTION
4 FILTER
5 DYNAMIC AND STATIC CORRECTIONS
6 DISPLAY

DECONVOLUTION INFORMATION
TIME VARIANT MINIMUM PHASE INVERSE FILTER
AUTO CORR. INT 3 ZONES OF .1575 MS
SEARCH ZONE .31 MS
OPERATOR LENGTH .75 MS
TIME ZONE 0.0-5.0 SEC

TIME VARIANT FILTER

TIME ZONE			L.C. (C.P.S.)	H.C.
0.0 - 2.0	SEC		20/24	66/74
2.0 - 3.5	SEC		16/24	44/50
3.5 - 5.5	SEC		10/24	32/36
5.5 - 9.0	SEC		8/24	20/24

PLAYBACK
RATE 1 INCH (1.0") = 1 SEC
REEL 52440

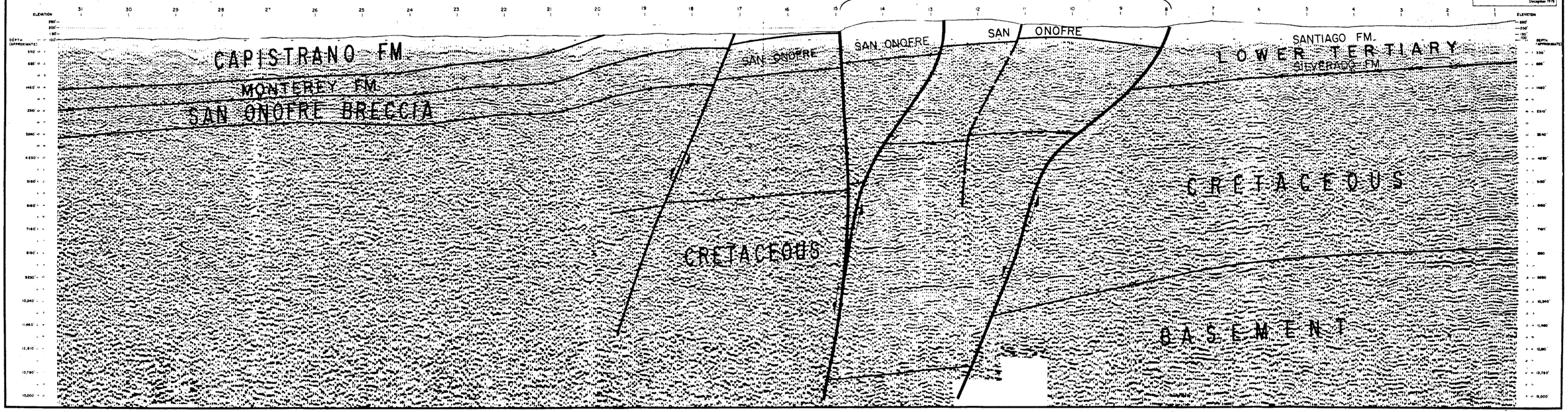
SOUTHERN CALIFORNIA EDISON COMPANY
Seismic Line No. N 152
PURCHASED FROM CHEVRON

GEOLOGIC ANNOTATIONS
By
Jack C. Vaus
Consulting Petroleum Geologist

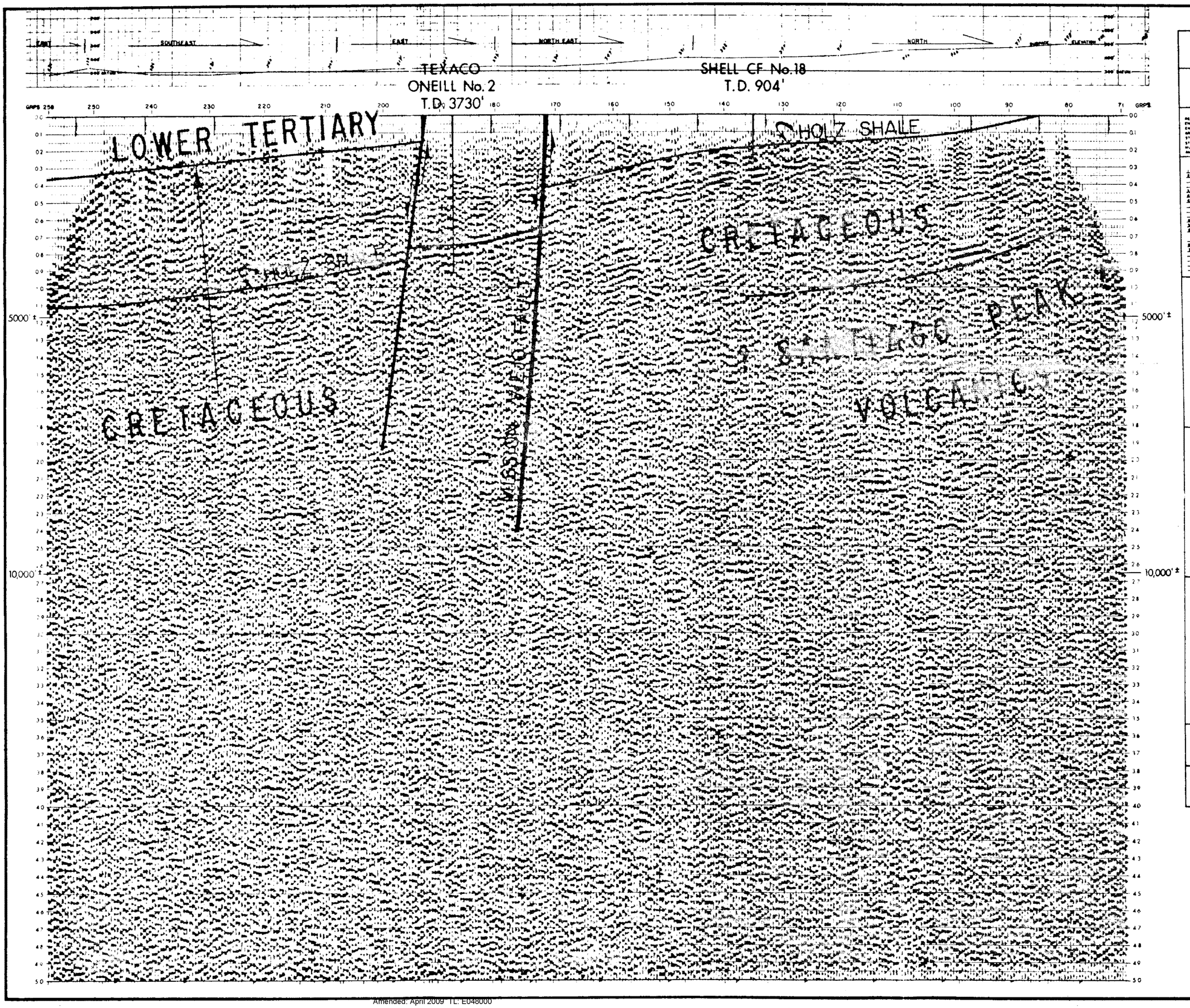
Note: Original records shot in 1954

For shot point locations refer to map - contours near top. Mainframe shots 1" = 4000 by J. C. W.

December 1978



Amended: April 2009 TL: E048000



LINE 8
V.P.'s 84 - 244
AREA ORTEGA
LOCATION ORTEGA HWY 74
DATUM 100

MOBIL OIL CORP.

FIELD RECORDING DATA

RECORDED BY G.S.I. PARTY 106 DATE JAN 1971
ENERGY SOURCE VIBROSEIS SWEEP FREQ. 8-36 SWEEP LENGTH 8 SEC
ENERGY PATTERN 3 VIBRATORS 110 SWEEPS INSTRUMENTS 12,000
GROUP INTERVAL 50 GROUP PATTERN 36 IN LINE
STANDARD SHOT POINT INTERVAL 500
STANDARD SPREAD 8500' 500' 0, 500' 8500'
MULTIPLICITY 12 FOLD RECORDING FILTER 12 TO 48 HZ
AMPLITUDE CONTROL AGC GAIN SAMPLE RATE 2 MS

DIGITAL PROCESSING SEQUENCE
PROCESSING SAMPLE RATE 2 MS

1. DIVERSITY STACK
2. CORRELATION
— TRACE EDIT
— GAIN REMOVAL AND TRUE AMPLITUDE RECOVERY
3. VELOCITY ANALYSIS
4. DATUM STATIC CORRECTION (CORRECTION VELOCITY 5000 f/s)
5. NORMAL MOVEOUT CORRECTION
— RESIDUAL MOVEOUT CORRECTION
— RESIDUAL STATIC CORRECTIONS
— TIME VARYING TRACE EQUALIZATION
6. 12 FOLD COMMON DEPTH POINT STACK
— FIRST BREAK SUPPRESSION
7. TIME VARIANT DECONVOLUTION 16 PTS 2 MS
NUMBER OF OPERATORS 4 GATE 4,000 MSEC
— TIME VARIANT INITIAL FILTER ___ PTS ___ MS
8. DIGITAL FILTER 33 PTS 2 MS
9. TIME VARIANT SCALING

NMO VELOCITY x 10³

DIGITAL FILTERING

FIRST BREAK SUPPRESSION

DISPLAY DATA

GEOPHYSICAL SERVICE INC

SOUTHERN CALIFORNIA
EDISON COMPANY
Mobil Vibroseis Line No 8
PURCHASED FROM MOBIL

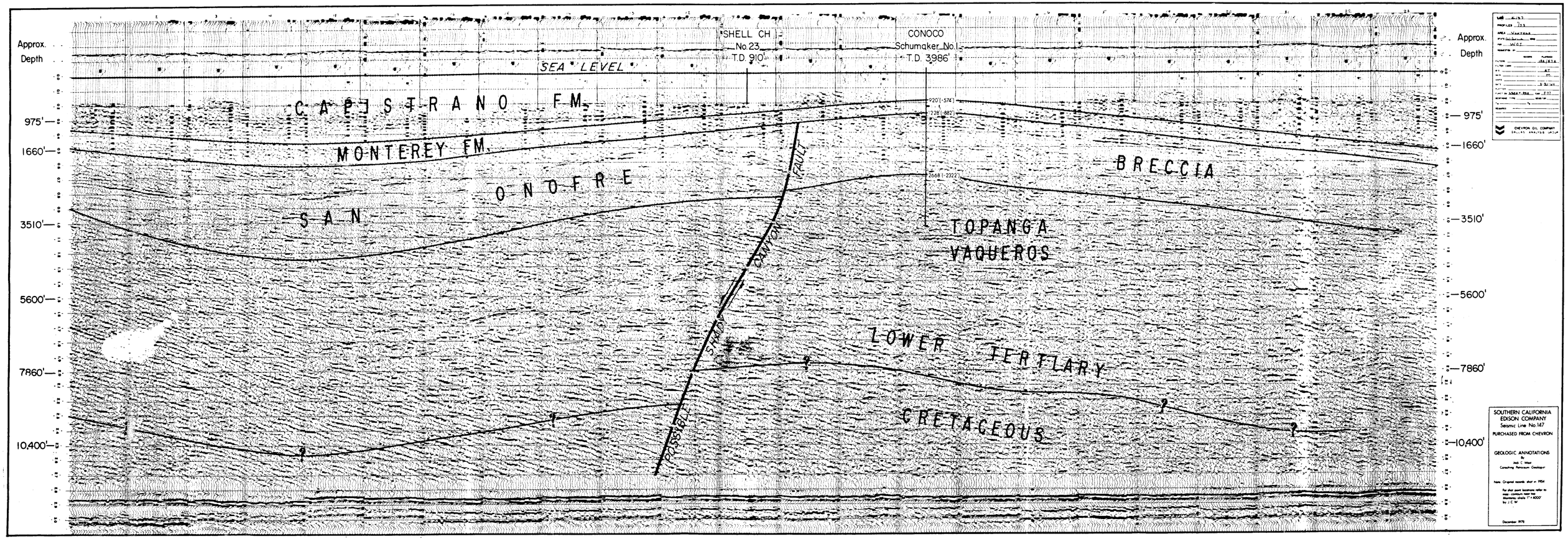
GEOLOGIC ANNOTATIONS
By
Jack C. West
Consulting Petroleum Geologist

Note Shot in 1971

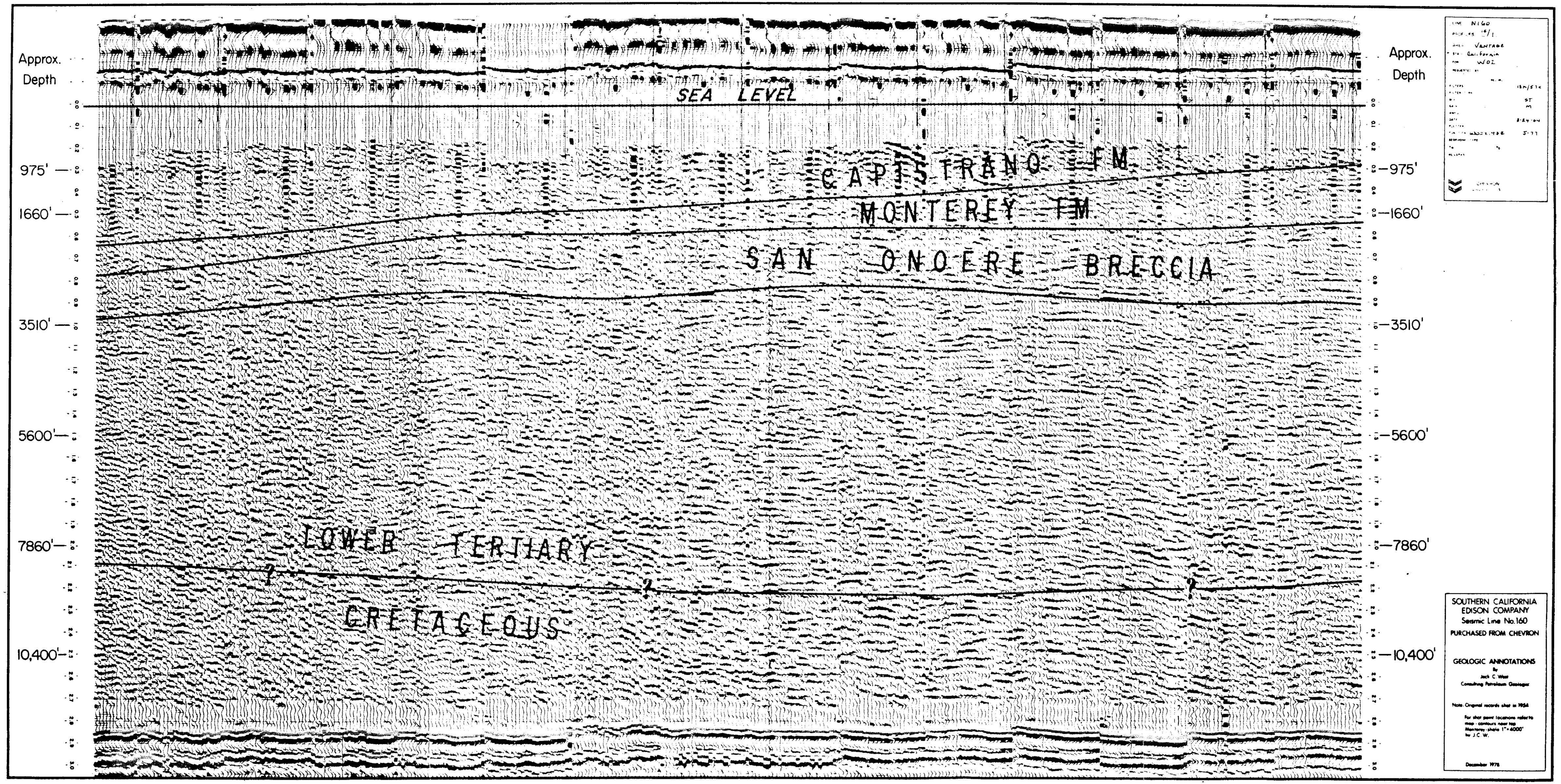
For shot point locations refer to map - contours near top Monterey - shale 1" = 4000' by J.C.W.

December 1978

Amended: April 2009 TL: E048000



Amended: April 2009 TL: E048000



Amended: April 2009 TL: E048000

APPENDIX 2.5I

PRESENTATION TO NRC/USGS

SEPTEMBER 1980

Site File Copy

ENCLOSURE 1

EDITED TRANSCRIPT OF DR. P. ELHIG DISCUSSION OF GEOLOGIC SETTING, SONGS AREA - SEPTEMBER 23, 1980

This is in response to questions raised concerning 1) the interrelationship between the Cristianitos fault and the Offshore Zone of Deformation (OZD) and 2) the likelihood of future seismic activity along the Cristianitos fault. The main conclusions presented here are:

1. The trend of the Cristianitos fault is parallel to and controlled by the structural grain of the Peninsular Ranges. The trend is not a product of wrench fault tectonics.

2. The Cristianitos fault is a westward-dipping normal fault which moved in association with subsidence in the Capistrano Embayment during the Late Miocene and Early Pliocene in the interval between about 10 and 4 million years (m. y.) before present.

3. Activity on the Cristianitos fault was caused by crustal extension in a westward direction and occurred simultaneous with the development of a deep submarine depression within the Los Angeles Basin.

4. The Cristianitos fault is probably a listric normal fault produced by gravity gliding into the Los Angeles Basin. The inclination of the Cristianitos fault probably decreases downward and merges into a bedding plane fault within deep strata of Cretaceous or Late Jurassic age.

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5. The Cristianitos has been inactive since Late Pliocene. The Cristianitos fault can no longer move because filling of the Los Angeles Basin prevents gravity gliding and because the tectonic stress has changed from extension in an east-west direction to compression in a northeast-southwest direction.

6. The open folds and minor faults observed in acoustic profiles in the nearshore area between the Cristianitos fault and the OZD do not represent an interconnection between the Cristianitos fault and the OZD. The displacement on the Cristianitos fault dies out near the coast as a result of downwarping of the coastal area underlain by thick deposits of San Onofre Breccia directly east of the Cristianitos fault.

7. Movement on the OZD would not trigger movement on the Cristianitos fault.

In order to understand the structural evolution of the region surrounding SONGS it is necessary to regress in time to the Mesozoic. At the beginning of the Mesozoic the North American Craton terminated along the eastern margin of the present Peninsular Ranges. During the Late Jurassic, sedimentary strata of Triassic and Jurassic age, referred to as the Bedford Canyon Formation near SONGS, were accreted against this part of North America, presumably as a result of eastward subduction of oceanic crust (Hamilton, 1978; Criscione and others, 1978). Volcanic and volcaniclastic rocks were emplaced on top of the accretionary wedge along the western side of the Peninsular Ranges during the Late Jurassic and Early Cretaceous (Gastil and others, 1975). Batholithic rocks intruded the accretionary wedge during the Cretaceous. The initial batholiths were emplaced along the west side of the Peninsular Ranges starting

about 120 m.y. ago but the belt of later intrusions shifted progressively eastward with time (Silver and others, 1979). Batholithic intrusion was accompanied by uplift and erosion, but, by Late Cretaceous, subsidence along the western margin of the Peninsular Ranges permitted the sea to transgress eastward to form a rugged shoreline near the western margin of the batholithic intrusions (Figure 1). As seen today, the eastern limit of Upper Cretaceous marine strata forms a relatively straight line from the Santa Ana Mountains at the northwest corner of the Peninsular Ranges to the Vizcaino Peninsula in Baja California. Gastil and others (1975, p. 47) refer to this as the Santillan and Barrera line in honor of the geologists who, in 1930, first called attention to it in a publication. The line was originally thought of as the eastern edge of a geosynclinal basin analogous to the Great Valley of California but in terms of modern nomenclature we would refer to it as a forearc basin. The Santillan and Barrera line is a tectonic hinge line separating the thick, buoyant, dominantly batholithic continental crust to the east from the westward-thinning, accretionary wedge which adjoins oceanic crust to the west. Downwarping to the west of this line was probably controlled primarily by isostatic adjustments and proceeded gradually through time in response to loading by sediments eroded from the continent to the east of the line.

The surface trace of the Cristianitos fault is subparallel to the Santillan and Barrera line and lies at an average distance of about 6 miles (10 km) west of it. As interpreted here, the Cristianitos fault is a westward-facing listric, normal fault which passes downward into a bedding-plane fault within the lower part of the post-batholithic Cretaceous strata or underlying Santiago Peak Volcanics which contain interfingered marine shale. Structural

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factors controlling the Cristianitos fault would be the westward dip of the deep strata and the eastward pinchout of clay-rich strata which might serve as surfaces of low shear strength during gravity gliding. Keep in mind that the dip of the strata would be essentially perpendicular to the Santillan and Barrerea line and that the dips would be steeper at the base of the sedimentary sequence than near the top because of the progressive westward tilting through time.

During the period from the Late Cretaceous through the Lower Miocene, the position and configuration of the coastline varied slightly, probably as a result of fluctuations in relative sea level and minor crustal warping. During the Eocene the coast transgressed landward across the Santillan and Barrera line but most of the time it was on the seaward side of the line. During the Lower Miocene (about 20 m.y. ago) the shoreline was immediately west of SONGS and trended north-northwesterly across the present Capistrano Embayment as shown diagramatically in Figure 2 (after Campbell and Yerkes, 1976). At that time the Vaqueros Formation was deposited under shallow marine conditions on the seaward side of the shoreline while the continental Sespe Formation was deposited on the landward side.

At the beginning of the Middle Miocene (about 16 m.y. ago) conditions changed radically along the southern California coast and adjacent offshore borderland. The change may have been brought on by passage of the East Pacific Rise beneath this part of the continental margin or by divergent transform faulting postdating the overriding of the rise. The major changes included: 1) the sudden appearance of Catalina Schist at the surface in the area offshore from the present coast with local shedding of schist debris in a

northerly to easterly direction to form the onshore occurrences of the San Onofre Breccia; 2) widespread volcanism including volcanic intrusions within and to the north of the San Joaquin Hills; and 3) crustal extension and fragmentation causing the initial opening of the Los Angeles Basin (Figure 3).

Figure 4 (after Stuart, 1979) shows the distribution of San Onofre Breccia which consists of Catalina Schist debris and the probable landward limit of schist bedrock. The juxtaposition of the schist against Peninsular Range basement is significant because the two formed in very different environments. Whereas the Peninsular Ranges basement formed in a shallow continental margin environment with batholithic magma believed to be derived from a subduction zone 125 to 175 km deep, the Catalina Schist experienced low temperature, high pressure metamorphism characteristic of a subduction zone at a depth of 30 to 40 km (Platt, 1974, 1976). The limited available data indicates the schist was metamorphosed synchronous with batholithic intrusion (Suppe and Armstrong, 1972); consequently, the two terraces were probably generated further apart than at present and have been brought together by faulting. In the area offshore from SONGS the contact between the two terraces is generally assumed to lie along the OZD but the presence of a thick sedimentary cover inhibits verification. The greatest known thickness of San Onofre Breccia is exposed on San Onofre Mountain east of SONGS where it was deposited on a piedmont alluvial fan (Figure 5). Details of its depositional environment in the SONGS area are described by Ehlig (1979) and Stuart (1979).

Volcanism was wide spread within southern California during the Middle Miocene but in the region around SONGS it occurred mainly within and to the north of

Amended: April 2009 TL: E048000

the San Joaquin Hills. Here, the volcanic rocks occur as flows and pyroclastic debris interbedded with the Topanga Formation and as intrusions along faults (Vedder and others, 1957; 1975). A southward plunging domal uplift developed in the San Joaquin Hills and area to the north simultaneous with emplacement of volcanic rocks. McCulloh (1960) has mapped steep-gradient positive gravity anomaly over this area. Although McCulloh suggested the anomaly might be caused by a gabbro intrusion in the underlying basement, it appears more likely that the area is underlain by a shallow laccolith of Middle Miocene age.

A microfaunal analysis of the Topanga Formation in the northwestern San Joaquin Hills indicates water depths increased from about 250 m (800 ft.) at the start of the Middle Miocene (16 m.y. ago) to about 1800 m (5900 ft.) in late Middle Miocene (about 14.5 m.y. ago) as determined by Ingle (1979) (Figure 6). This reflects the initial opening of the Los Angeles basin. As subsidence progressed thoughout the area and a silled basin with oxygen-deficient bottom water developed, sedimentation changed to the laminated diatomaceous shale of the Monterey Formation and the paleogeography was as shown in Figure 7. In the areas southeast of SONGS massive sandstone deposited as small submarine fans interfingers with shale in the Monterey Formation. This reflects the presence of a relatively steep submarine slope along the western margin of the Peninsular Ranges.

About 10 m.y. ago during the Late Miocene, the Cristianitos fault began to move in association with subsidence in the Capistrano Embayment as described by Ehlig (1979a). The initiation of faulting occurred while the area was below sea level and is marked by a change in sedimentation from the dominantly

laminated diatomaceous strata of the Monterey Formation to the poorly bedded mudstone, siltstone and sandstone of the Capistrano Formation. Beds within the two formations are concordant and are gradational in lithology within the interior of the embayment but are discordant and change abruptly from shale to sandstone adjacent to the Cristianitos fault. During deposition of the Capistrano Formation, two large submarine fans had their heads along the base of a west-facing submarine scarp along the Cristianitos fault . One is in the northeastern part of the Capistrano Embayment and is represented by massive sandstone of the Oso Member of the Capistrano Formation. Recent grading for residential development along the west side of the Cristianitos fault east of Oso Creek has created excellent temporary exposures of the contact between the Oso Member and underlying Monterey Formation. Here, conglomeratic sandstone of the Oso Member rests upon a scoured surface cut on slightly upturned beds of Monterey shale. In one place, Oso sandstone abuts against Monterey shale along a steep-sided channel wall which was previously mapped as a fault by Vedder and others (1975). The sand of the Oso Member was probably fed into the area by the ancestral Trabuco Creek which drained across the present trace of the Elsinore fault. The second submarine fan had its head along the Cristianitos fault in the area between. SONGS and San Mateo Creek and, although its massive sandstone is referred to as the San Mateo Formation, it interfingers with and is part of the Capistrano Formation. The coarsest part of the fan-head deposits is restricted to a small area between San Onofre and San Mateo Creeks. This suggests that the fan was fed by a submarine canyon cut into the scarp along the Cristianitos fault, probably the ancestral San Mateo Creek which drained a large area extending east of the Elsinore fault during the Late Miocene.

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Simultaneous with the development of the Capistrano Embayment, the Los Angeles Basin deepened rapidly in the vicinity of Newport Bay on the west side of a submarine ridge which occupied the present position of the San Joaquin Hills. Faunal Analyses by Ingle (1979) indicate water depths were at least 3,000 m (9840 ft.) in the Newport Bay area during the Late Miocene (Figure 8). At the same time water depths were a maximum of 2,500 m (8,200 ft.) in the Dana Point-Capistrano area at the mouth of the Capistrano Embayment (Figure 9). The paleogeography for this period is shown in Figure 10. Notice that the arrangement of the Doheny and San Mateo submarine fans indicate a relatively steep south-facing submarine slope existed at the mouth of the Capistrano Embayment with a deep ocean basin to the south.

Faulting, which occurred in the area of the San Joaquin Hills during the Middle and Late Miocene, was probably caused by extension associated with domal uplift and gravity gliding toward the Los Angeles Basin. Most of the faults trend between north and north-northwest and are steeply dipping with the west side down. In cases where the east side of a fault is down, the fault pattern commonly suggests a graben structure. The cross section in Vedder and others (1975, Figure 10) favors a gravity glide origin for the Pelican Hill fault. The diagnostic features are the decrease in the dip of the fault plane with depth and the reverse drag along the down thrown side of the fault. The Pelican Hill fault has a stratigraphic separation of about 6,000 feet, which could easily be accommodated by gravity gliding into the Los Angeles Basin where crustal extension and basin deepening removed lateral support from the west flank of the San Joaquin Hills structural high.

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Movement on the Cristianitos fault and extension within the Capistrano Embayment is also probably the result of gravity gliding in a westward direction into the Los Angeles Basin. That the Cristianitos fault is a west-facing normal fault can readily be seen in the coastal exposure southeast of SONGS. Here, the fault dips 57 degrees west with slickensides oriented down the dip. The west side is down and reverse drag on the downthrown side indicates a flattening of the fault plane with depth (Ehlig, 1977, Figure 4). Similar features exist along the fault within the Capistrano Embayment. For example, cross section C-B by West (1978) shows reverse drag on the down side (west) of the fault. Cross section C-B indicates a regional dip of about 15 degrees west along the base of the Cretaceous to the east of the Cristianitos fault where the structure is well known. Although cross section C-B indicates gentle dips along the base of the Cretaceous beneath the Capistrano Embayment, structural control is restricted to the upper half of the sedimentary sequence. The base of the Cretaceous sediments is likely to continue to dip westward beneath the Capistrano Embayment as a result of westward thickening and the addition of older strata at the base of the sequence in the seaward direction from the Santillan and Barrera line. The base of the Cretaceous may also dip westward beneath the San Joaquin Hills structural high if the domal uplifting of the high was the result of a Middle Miocene laccolithic intrusion as appears likely. The Cristianitos fault is likely to flatten with depth and become a bedding plane fault near the base of the Cretaceous sediments. Movement on the Cristianitos fault was probably caused by gravity gliding of the hanging wall block and was the result of inadequate lateral support within the Los Angeles Basin where the ocean floor was very deep and where the westward continuation of the Middle Miocene and older rocks of the Peninsular Ranges had been removed by crustal extension

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and/or strike slip faulting. It should be noted that Los Angeles Basin had a different configuration during the Late Miocene and Early Pliocene than at present. A deep trough extended southward across the present coast to the west of the San Joaquin Hills structural high whereas a northwest-trending structural high has subsequently developed along the landward slide of the coast to the west of the San Joaquin Hills. This is shown by the fact that Upper Miocene strata exposed above sea level on the west side of San Joaquin Hills were, according to Ingle, (1979), deposited at an ocean depth of about 10,000 feet (3,000 m) whereas strata of the same age are 20,000 feet below sea level within the deepest part of the present Los Angeles Basin.

The Cristianitos fault appears to have stopped moving about 3 or 4 million years ago during the Pliocene in association with filling of the Los Angeles Basin and the start of a new tectonic regime involving uplift (Figure 11). The Capistrano Embayment emerged above sea level during deposition of the Niguel Formation in Late Pliocene. The greatest uplift has occurred along the present coast where strata, which were deposited at a depth of 6,500 feet (2,000 m) during the Early Pliocene (Ingle, 1979), are now above sea level. The uplift is occurring along a northwest-trending arch as indicated in Figure 12. The uplift is interpreted to reflect crustal compression oriented in a northeast-southwest direction with the axis of least compressive stress oriented vertically. This present tectonic regime is probably the result of compression across the bend in the San Andreas fault. Most of the activity on the Cristianitos fault and associated opening of Capistrano Embayment predates 240 km of right slip on the San Andreas fault and occurs at a location far from the bend in the San Andreas fault.

One of the most puzzling problems associated with the Cristianitos fault has been the nature and cause of its southward termination. In spite of the fact that the fault is well exposed in the sea cliff southeast of SONGS, it cannot be located in the offshore area. The most likely explanation is that the fault dies out immediately offshore with part of the dying out being accommodated by downwarping toward the southwest as seen in Woodward-Clyde sparker profile 849. The fault probably dies out because of a change in the physiography and geologic structure which existed in the vicinity of the present coast during the Late Miocene and Early Pliocene. In the inland area to the east of the Cristianitos, exposed bedrock consists mainly of Eocene and Cretaceous strata striking nearly parallel to the fault and dipping gently in a westerly to southwesterly direction. The San Onofre Breccia forms the principal exposed bedrock east of the fault near the coast. It strikes in northwesterly to westerly directions at an angle to the Cristianitos fault and dips seaward at angles typically ranging between 35 and 45 degrees along the south flank of the San Onofre Mountains (Ehlig, 19779). If this change in structure is present at depth to the west of the surface trace of the Cristianitos fault, it would tend to prevent gravity gliding toward the Los Angeles Basin in the area south of the present coast and the steeping of the dip would tend to cause the Cretaceous beds to be buttressed. An alternate possibility is that the downwarping of the coastal area southeast of the Cristianitos fault tended to reduce the gravitational driving force along the southern edge of the gravity glide block causing displacement to die out in the offshore area. Other possibilities exist but they do not alter the conclusions that the Cristianitos fault dies out a short distance offshore.

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Neither do they alter the conclusion that the Cristianitos fault is presently inactive and has been demonstrably inactive since it was overlain by the coastal terrace about 125,000 years ago and has probably been inactive since the Pliocene. The present tectonic and physiographic setting are inconsistent with future activity along the Cristianitos.

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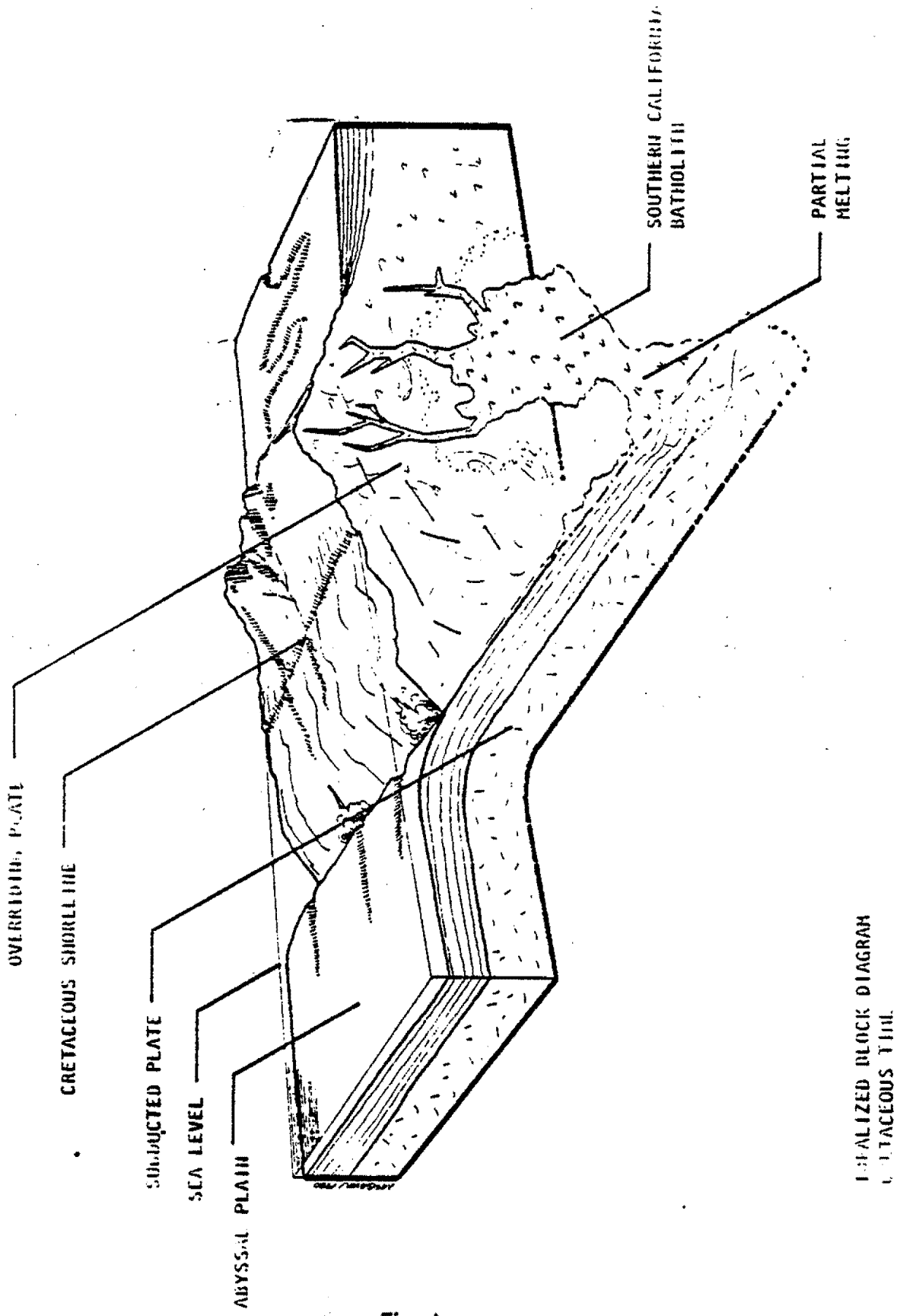
OVERRIDING PLATE
CRETACEOUS SHORELINE
SUBDUCTED PLATE
SEA LEVEL
ABYSSAL PLAIN
SOUTHERN CALIFORNIA
BATHOLITH
PARTIAL
MELTING
IDEALIZED BLOCK DIAGRAM
CRETACEOUS TIME

Fig. 1

20 MILLION YEARS bp

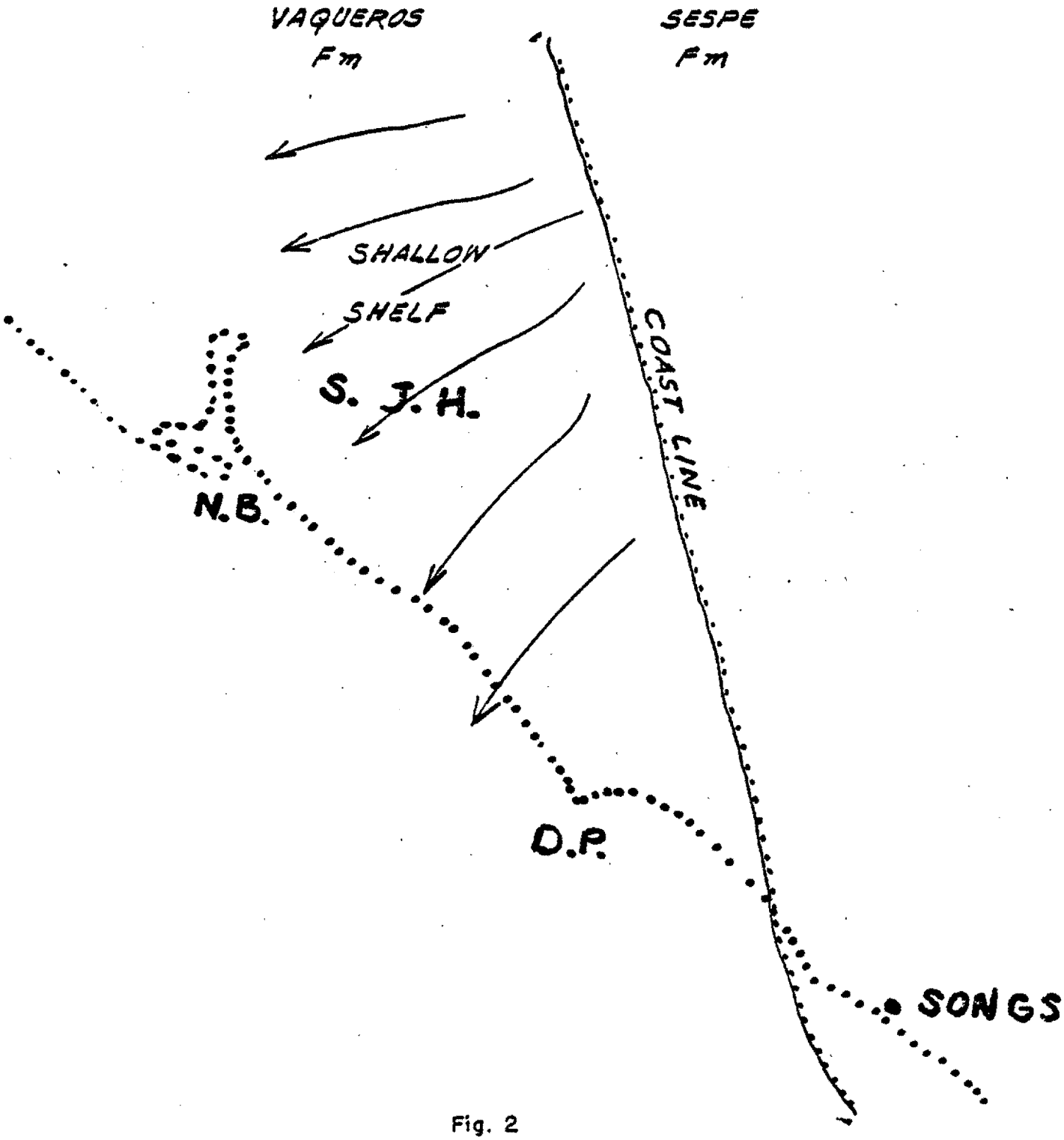

Fig. 2

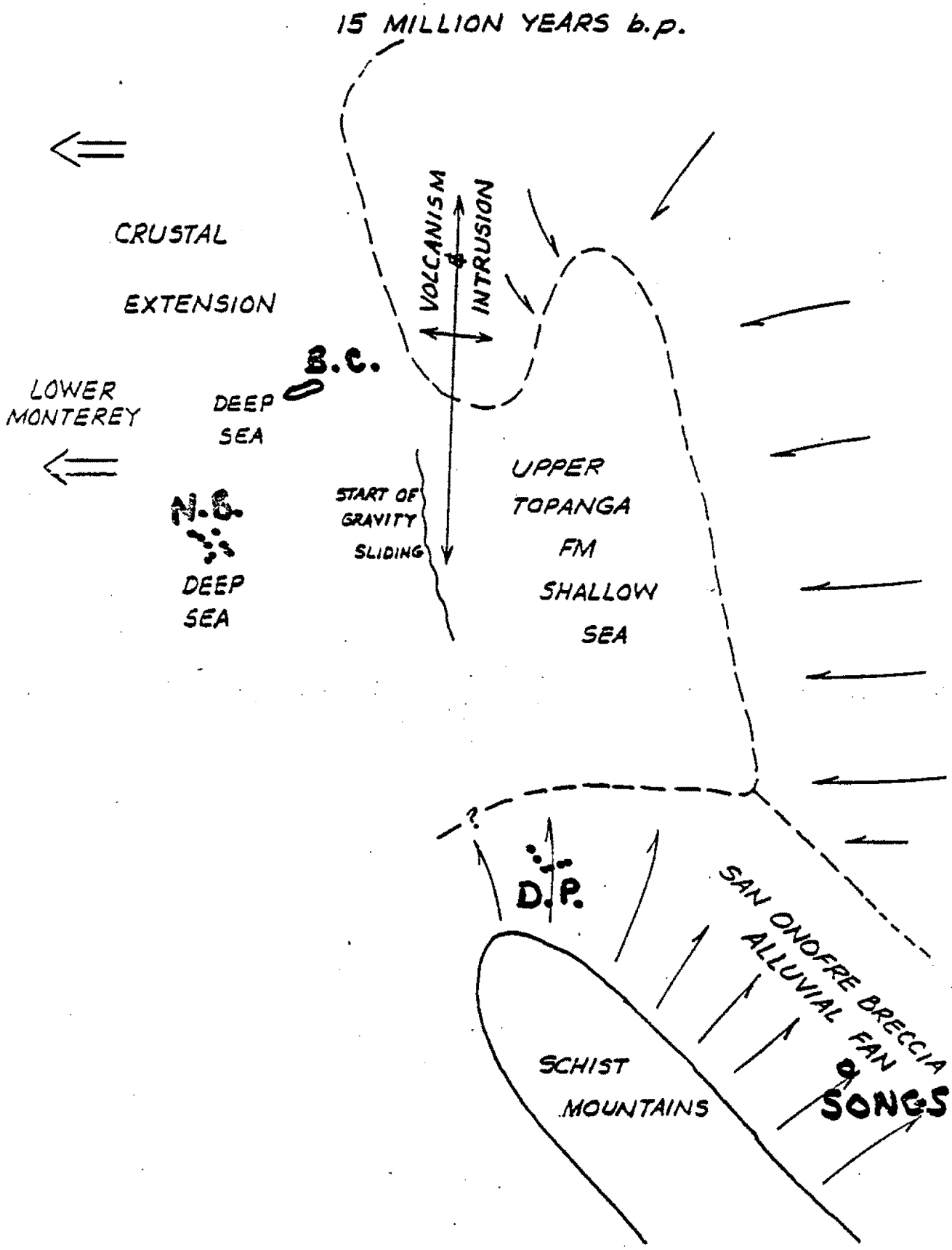

Fig. 3

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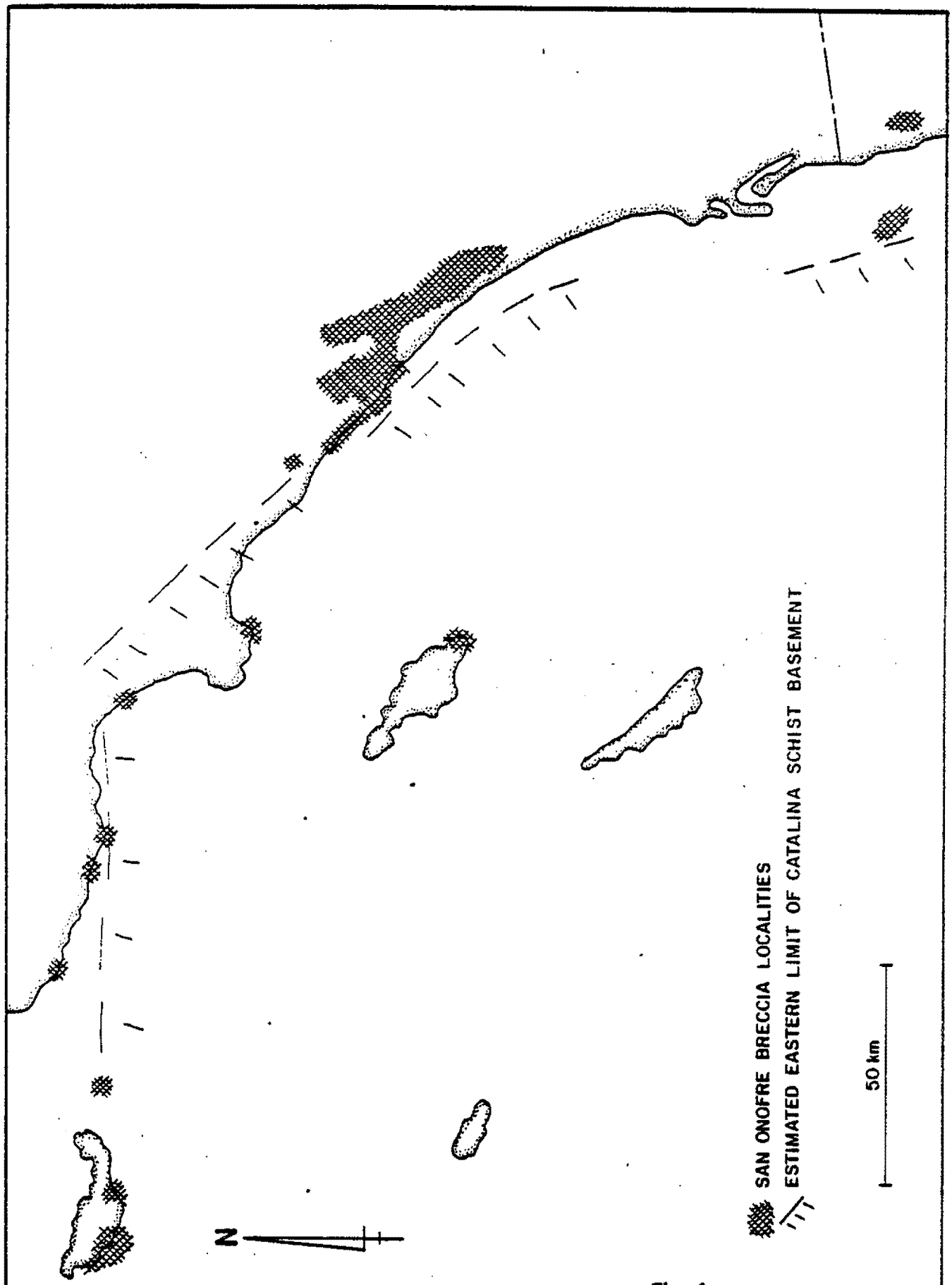
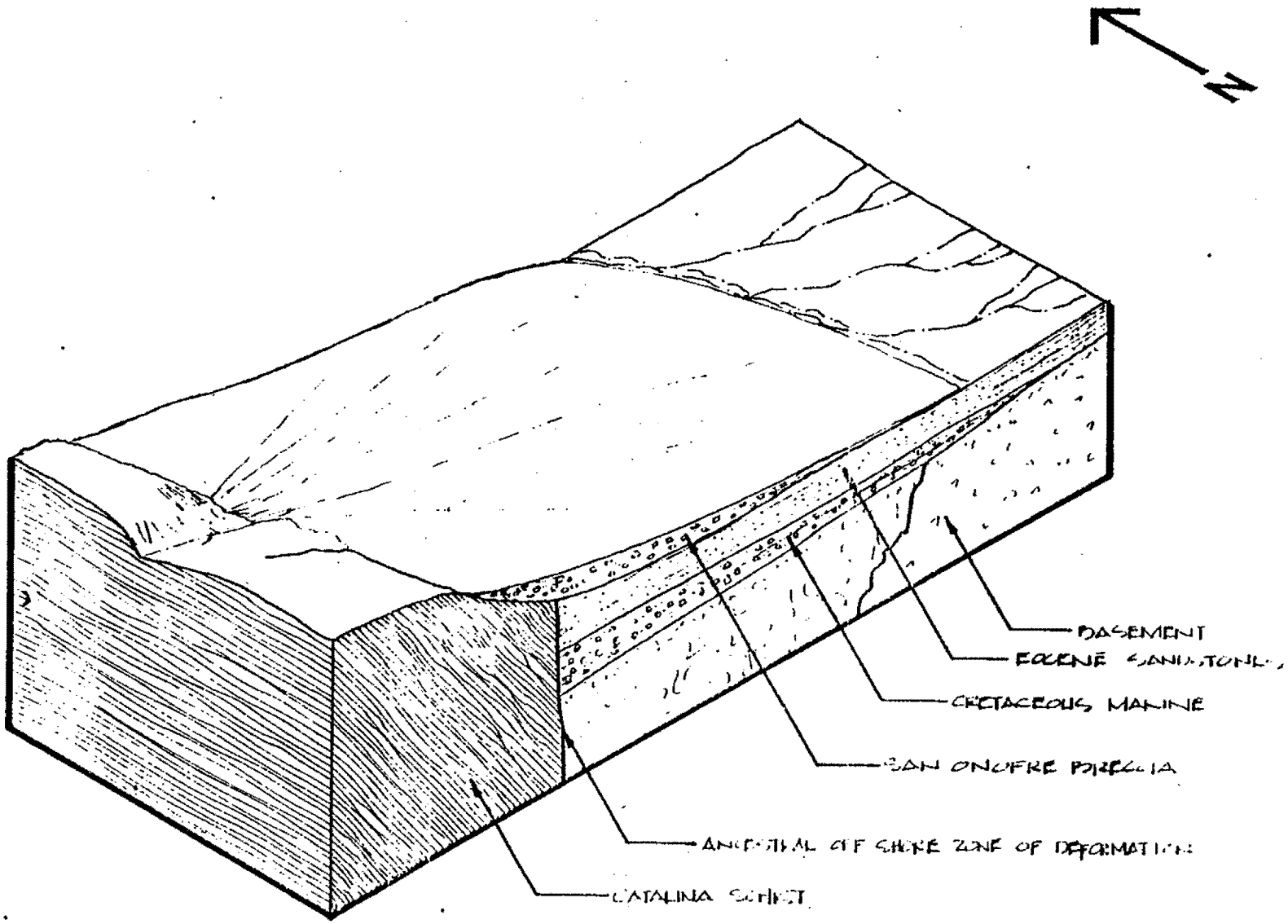


Fig. 4 (AFTER STUART, 1979)



IDEALIZED GEOLOGIC BLOCK DIAGRAM
DEPOSITION OF THE SAN ONOFRE BRECCIA

Fig. 5

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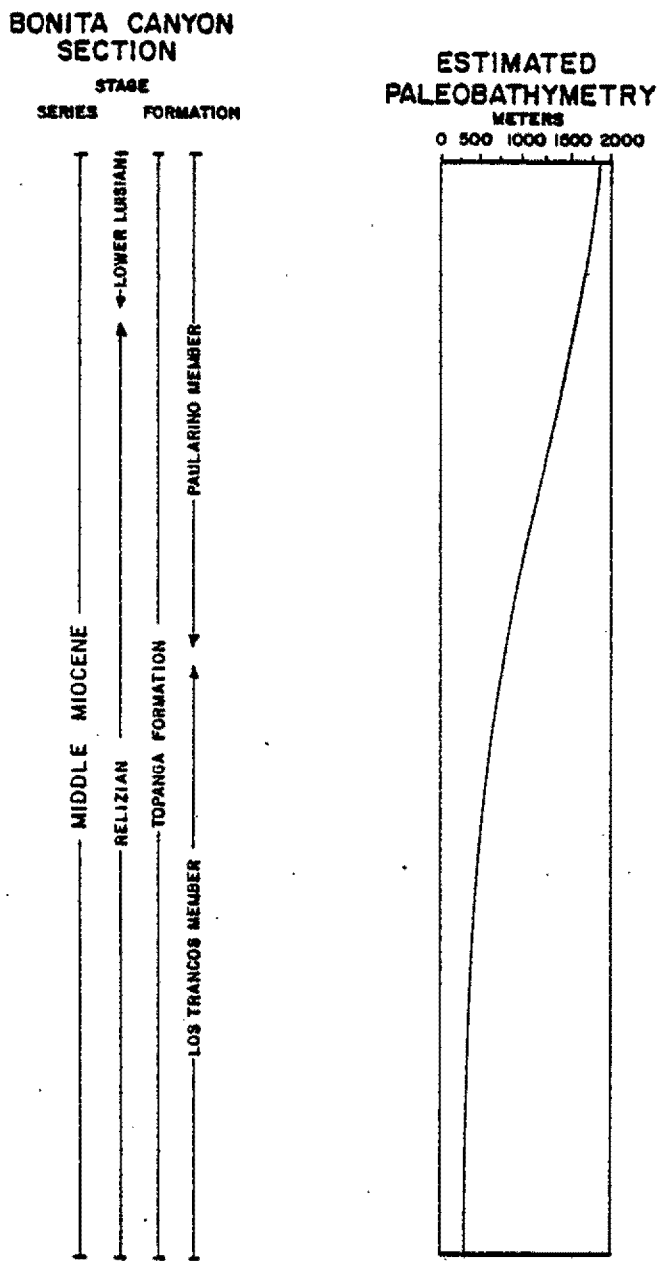
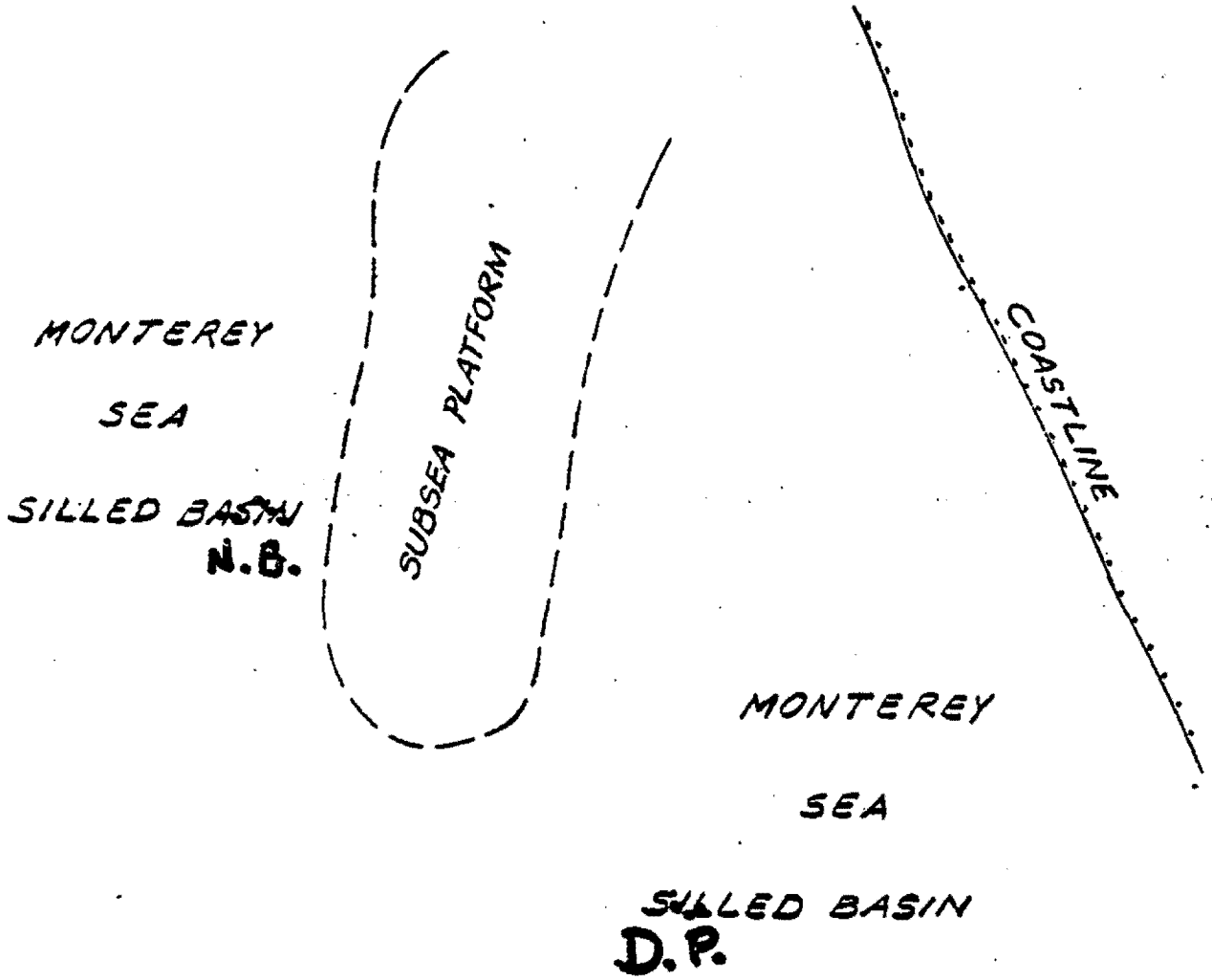


Figure 6 (AFTER INGLE, 1979)

13 MILLION YEARS b.p.



SONGS

Fig. 7

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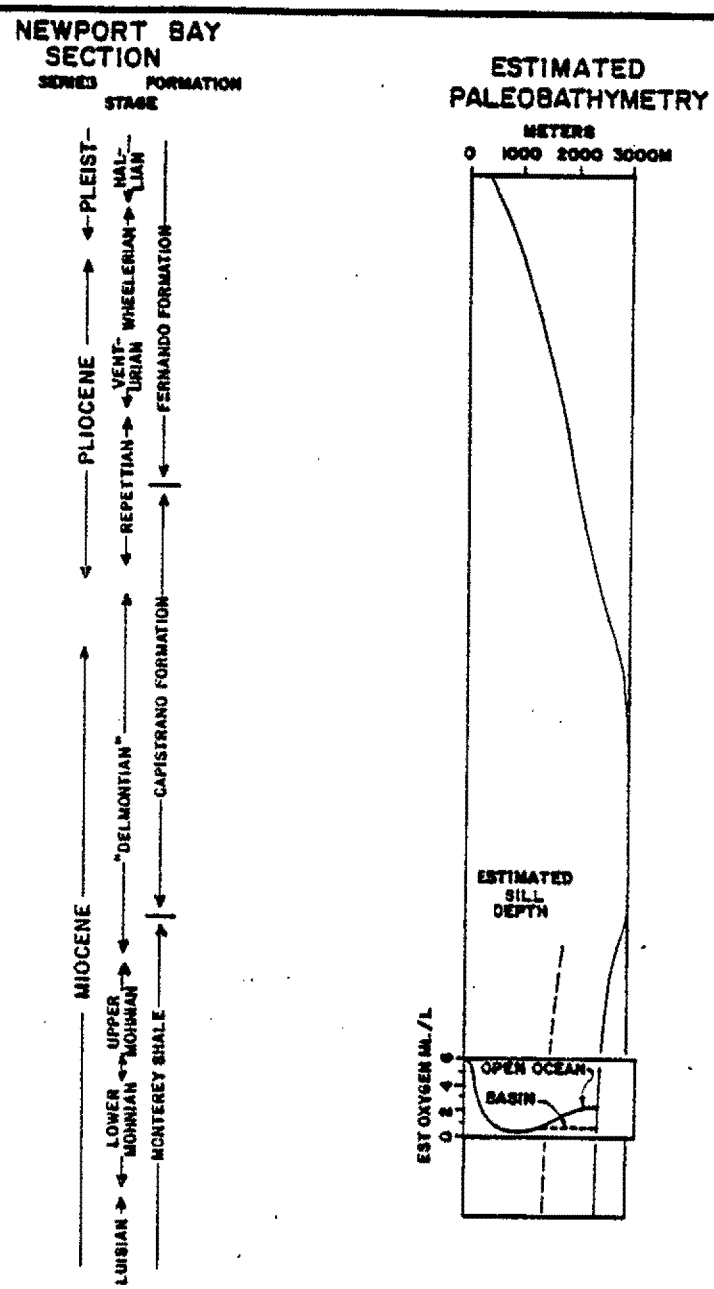

Figure 8 (AFTER INGLE, 1979)

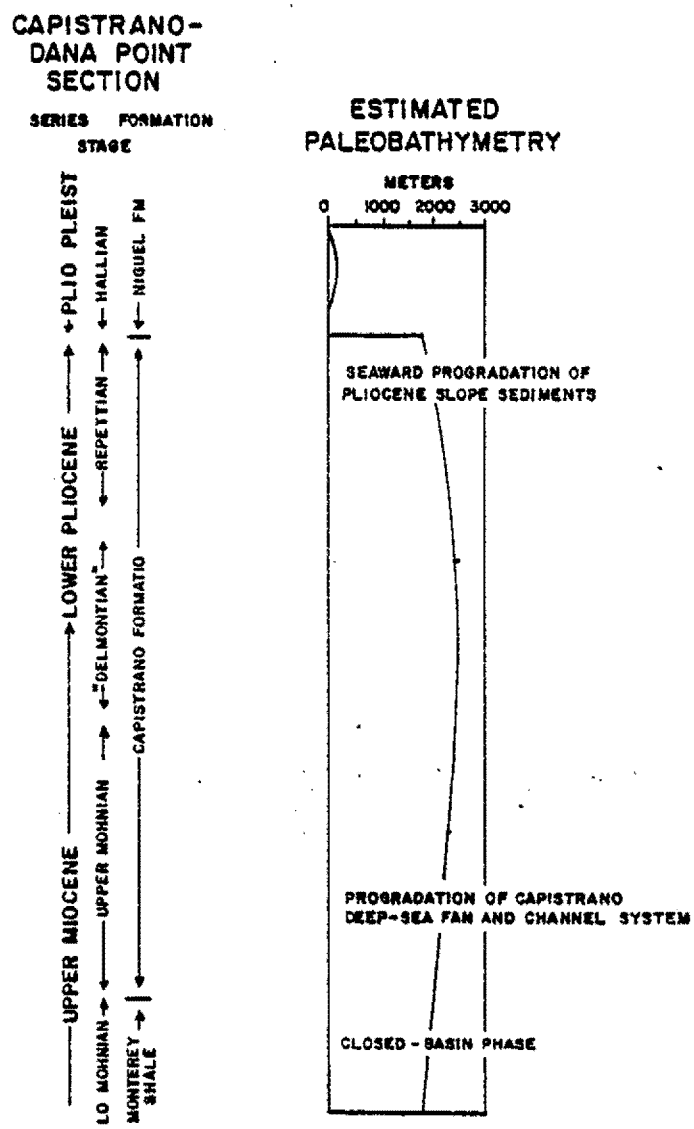

Figure 9 (AFTER INGLE, 1979)

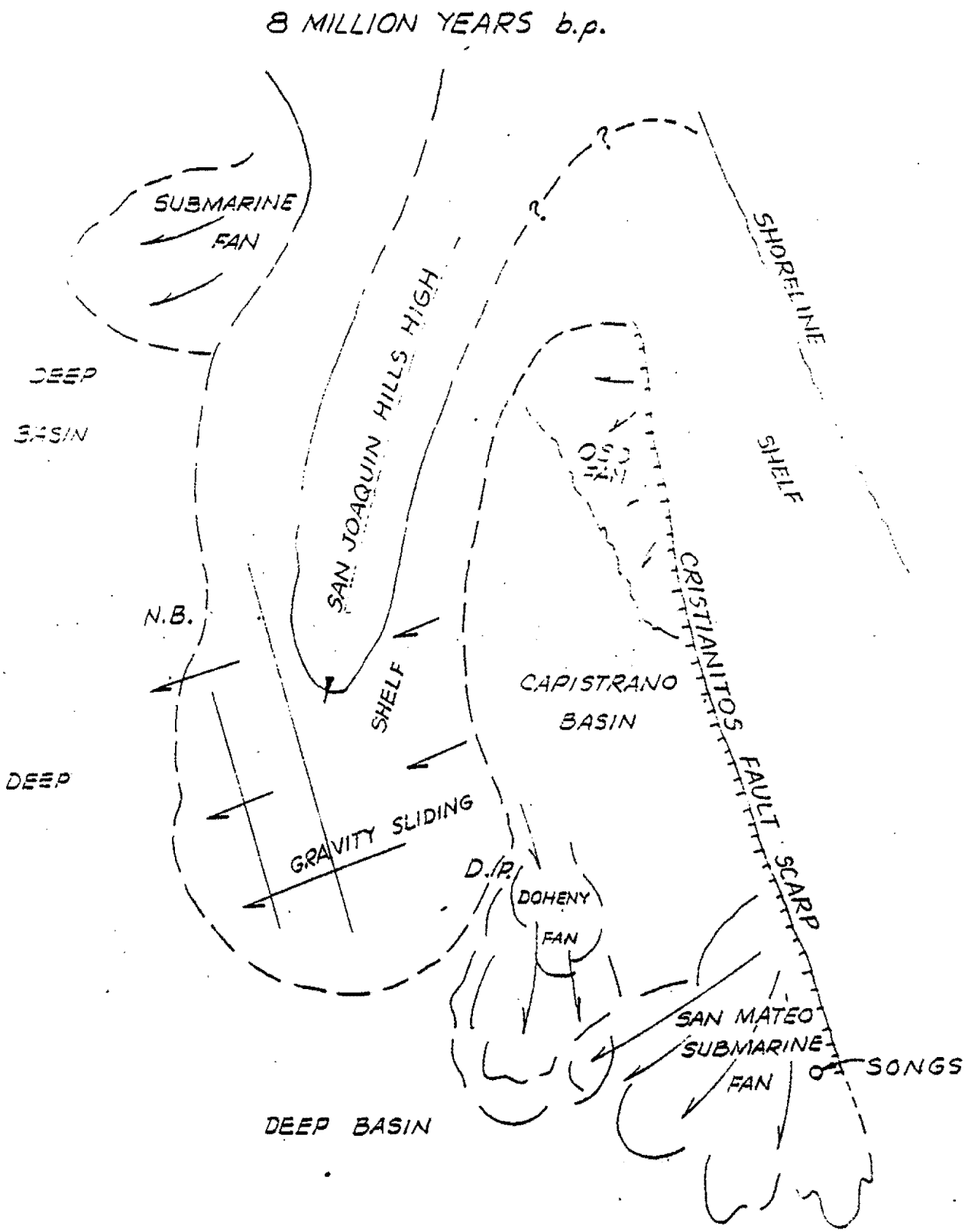

Figure 10

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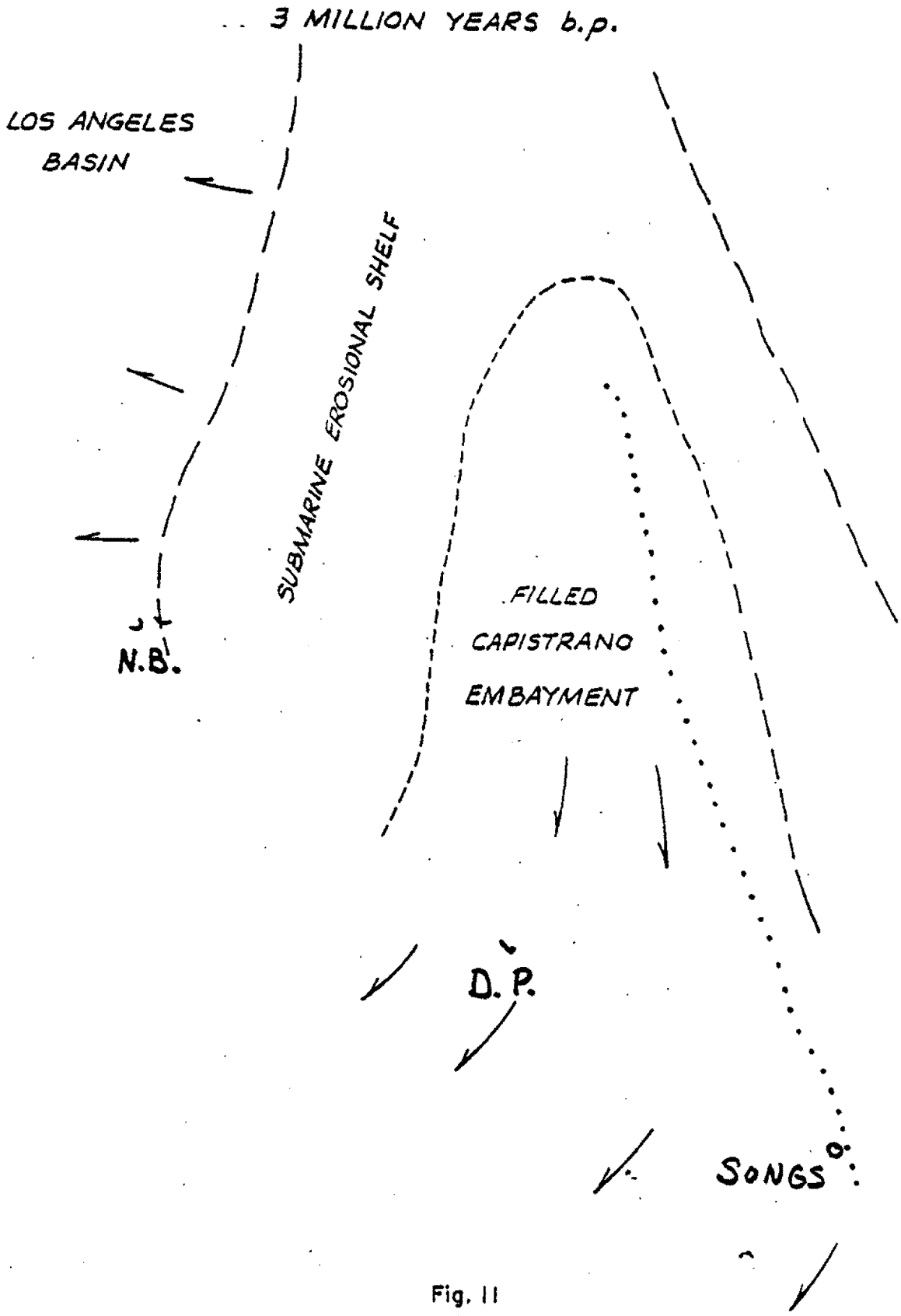
3 MILLION YEARS b.p.
LOS ANGELES BASIN
SUBMARINE EROSIONAL SHELF
FILLED CAPISTRANO EMBAYMENT
N.B.
D.P.
SONGS

Fig. 11

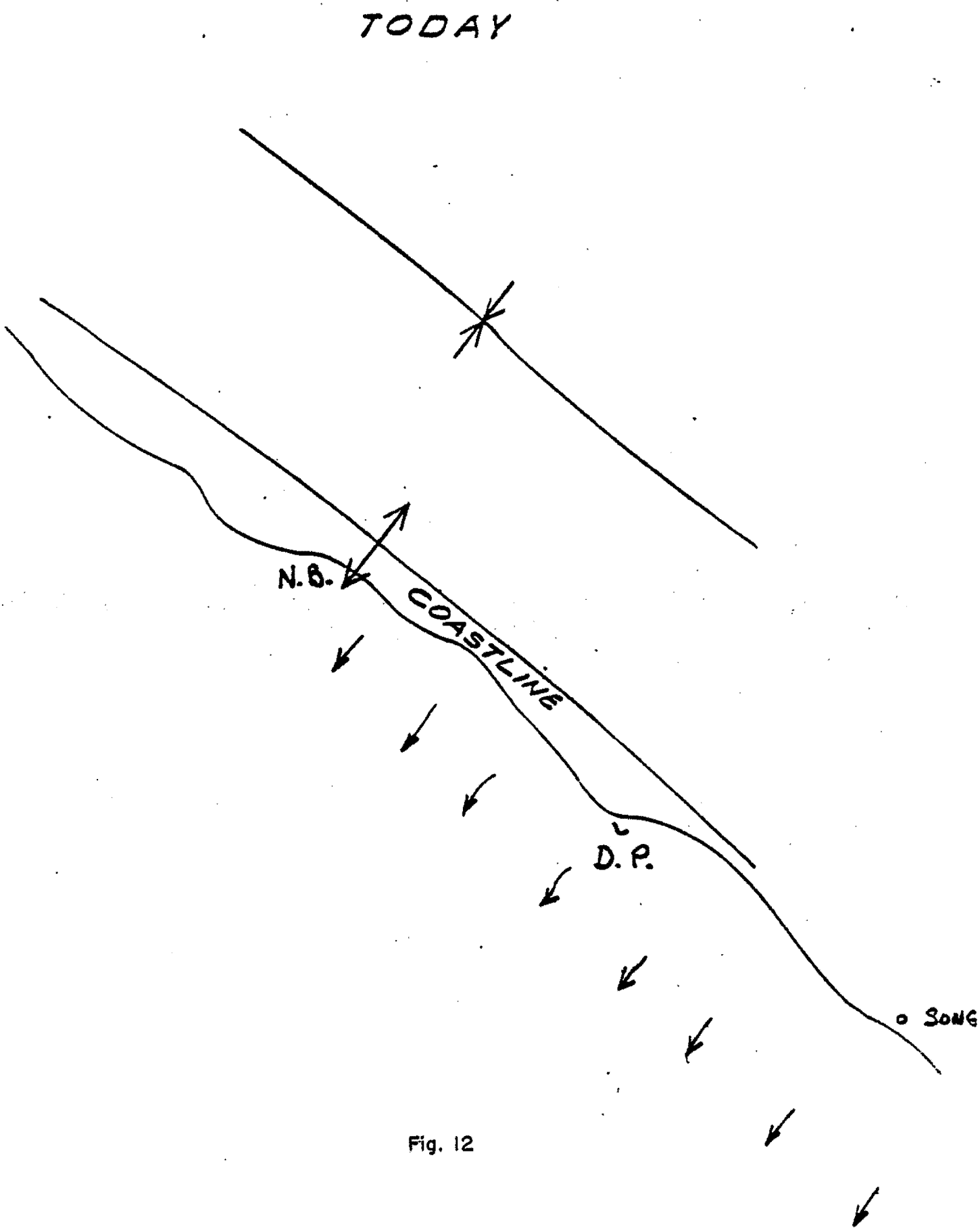

Fig. 12

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ENCLOSURE 2

EDITED TRANSCRIPT OF
DR. D. MOORE DISCUSSION OF OFFSHORE RECENT
SEISMIC REFLECTION PROFILES SEPTEMBER 23, 1980

This first slide (Fig. 13) shows track lines of the majority of the seismic reflection data now available to us. For your orientation, let me point out the coastline and the locations of SONGS and the onshore Cristianitos Fault where it meets the shoreline. The chart includes some early sparker data by Marine Advisors and General Oceanographics which is scattered rather widely through the area off SONGS in a reconnaissance network. Also included are several 3.5 KHz transects and a few of the high powered, deep penetration data lines of Western Geophysical. Please note the dart cores sample locations, shown in red. These have provided samples from which paleontological data have given ages for rocks that we can see in our recorded seismic sections. Most significant to this discussion are these close spaced Woodward-Clyde sparker transects on the shelf just south of SONGS and the detailed NEKTON water-gun survey lines that extend from the Woodward-Clyde data south to Oceanside. The Woodward-Clyde data, collected in 1978 for studies in connection with a possible LNG terminal site, have allowed us to study geological structure in this area in unusual detail. These Woodward-Clyde data were specifically examined with the intent of tracing an offshore extension of the Cristianitos Fault. The close spacing of the lines allows a high degree of confidence in correlating geologic structure from one line to the next.

The 1980 NEKTON water gun survey lines are also close spaced and were specifically positioned and collect to cover the area south of the Woodward-Clyde data, where an offshore projection of the onshore Cristianitos Fault trend might intersect the hypothesized OZD (HOZD).

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The following conclusions result from extensive studies of the data:

1) The seismic data do not reveal a seaward extension of the Cristianitos Fault beyond about 6,000 feet.

2) The faults east of the HOZD are of two kinds: First, there are those deep in the section that cut acoustic basement which in this area is the San Onofre Breccia. These older, deeper faults do not extend significantly upward into the oldest Monterey formations. Therefore, they cannot be related to a possible extension of the Cristianitos Fault. The second type of faults are those associated with a anticline-syncline pair that trends more northerly than the HOZD does across the shelf area south of SONGS. These faults, associated with the folding, are largely interformational and are generated by the folding. Most of the faults do not extend deep into the section or upward to the seafloor or the Pleistocene erosional unconformity. They are not present in strata younger than the latest Monterey and are thus older than at least about 5 million years.

The next slide (Fig. 14) shows selected sections of the northern Woodward-Clyde seismic lines. Horizontal scales vary somewhat from profile to profile as a result of ship speed changes during the shooting. On these illustrations, the average horizontal scale is shown by the bar graph line indicating 5,000 feet.

The vertical scales are 1 second of reflection time and are all equal. As a result of the short spacing on these lines, which is related to the ship's speed when they were run, the profiles have a vertical exaggeration of about 6 to 1. This is useful when interpreting the records, because it emphasizes

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features which otherwise would be difficult to see. To illustrate vertical exaggeration, note that on these illustrated profiles the apparent dip is about 16 to 17 degrees. It is actually about three degrees.

The colors on the geophysical profiles are to emphasize the degree of folding that has occurred in the younger part of the total recorded section. The contacts between the colored sections are based upon well defined unconformaties. The youngest unit, shown in the lavender color, is Plio-Pleistocene sediment that is acoustically transparent. That is, it is without good internal reflectors. We believe that it is a very soft sediment underlying Pleistocene terrace deposits. The underlying green unit is unconformable and laps onto the blue unit beneath it, as you can see in the illustrated profiles. This green unit is known, from dart core paleontological data (Response to NRC question 361.63), to be Delmontian in age and equivalent to the Capistrano formation. It, therefore, ranges in age from 4 to 6 million years and perhaps older. Below the basal Capistrano unconformity the blue colored section is latest Monterey formation. The deeper uncolored strata are the older portions of the Monterey. The ages of the units below the green are assumed as they are not directly penetrated by dart cores. Strata flanking the HOZD are sampled, however, and they are known to be Mohnian in age (Monterey Fm).

Within the three colored units there is an increased degree of folding with depth. It is clear that sedimentation has occurred with the folding as indicated by the unconformities. The most pronounced intensification of the folding with depth has taken place beneath the blue youngest Monterey unit.

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We will now examine the major features that are shown by this series of sections. The HOZD which occurs out near the edge of the shelf is best developed as we go south towards the central portion of the sections. Here the HOZD is displayed as prominent complex anticline or anticlinonoriam, that in most places, although not everywhere, is prominently faulted. As seen in these selected sections, the OZD and its contained faults commonly extend up to the sea floor, where the Monterey formation is outcropping or slightly covered by young outer shelf deposits. One of the most persistent features seen in these profiles is the broad asymmetrical syncline developed along the east flank of the HOZD. As is illustrated by the onlapping relationships, you can see that the folding which took place in the HOZD and to the east was accompanied by deposition of the younger sediments. The Capistrano formation in places, pinches out against the youngest Monterey formation. In other places it does not entirely pinch out, but instead it laps across the youngest Monterey folding.

East of the HOZD and its east flank syncline we see the other clearly defined feature of the area. That is the broad, low amplitude, more northerly trending anticline and syncline couple that exists beneath the shelf sediments east of the HOZD. Although one can see the multiple smaller anticlines and synclines developed in this general area, it is clear that the primary features are the broad anticline and syncline with the complicating smaller structures superimposed. These principally broad low amplitude folds have some faults within them. These faults, we believe, are the result of the folding or bending of the thick Monterey sediments. The Monterey formation, as Perry Ehlig has pointed out, is a soft, fine-grained commonly impermeable material deposited in an oxygen-poor environment. A thick section of that

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kind, if bent even slightly, can develop very high pore pressures and consequent low strength. When gently folded, these sediments typically develop many anticlines and synclines along the crests of large anticlines. Along with this, they develop very commonly intra and interformational faulting both in the anticline's and syncline's axes. This type of faulting is well developed as illustrated in sections 836, 839 and 841. In addition to this interformational faulting associated with folds, several deep faults occur in the uncolored section in what appears to be the acoustical basement, probably the San Onofre Breccia. These prominent faults in the acoustic basement occur in the eastern part of the area studied. These old faults, however, cannot penetrate significantly up into the overlying older Monterey, because we see unbroken seismic reflectors through the section slightly above them.

Turning now to a section showing a detail from line 836 (Fig. 15): The position of the detail is identified in the series of sections. This detail is intended to explain a fault at this location. However, if we look at the untouched enlarged original profile, we can see that there is considerable continuity to the section near the top of the syncline, but with depth there appears to be some fuzziness of arriving defractive signals. This is probably a function of bedding plane slippage; the result is relatively tight folding with slippage much like slippage along the leaves of a book. Because the "leaves" are stacked one on top of another, the subject slippage resembles a single fault in section. Again, it appears to be an intra-formational feature and does not extend up to the Pleistocene unconformity as we can see reflectors passing across the location where the fault would project.

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The next detail is from profile 841 (Fig. 16), identified in the series of sections from the earlier figure. This is a similar section showing clear evidence of through-going bedding passing beneath "book leaf" type intra-formational faulting. It appears that there is continuity of reflectors above this feature as well, although somewhat obscured by the bottom mutiples in the seismic profile. The interpretations of this section are shown in line drawings below the untouched profile.

Next, I will discuss a somewhat different situation as exemplified in the detail of section 847 (Fig. 17) from a region east of the folds. We have indicated a fault here overall in the section. However, as we look at it very closely in the detail, it is difficult to see exactly where the fault should be located. Again, there is probably continuity of bedding across the top of it. With regard to this zone, where it is difficult to trace the bedding plane reflectors through, this type of feature is typical of sections of Monterey formation that have high quantities of gas diffused through the sediments. There are other explanations for this type of record, but gas diffusion is the most plausible explanation for the feature. The line drawing interpretation of this detail is shown in the lower half of the illustration.

The next slide (Fig. 18) shows a series of Woodward-Clyde profiles to the south. These sections again show the linear features of the northern section proceeding to the south. The HOZD is very prominently displayed in the upper three of these records. Again we can see the very well developed asymmetrical syncline that lies on the east flank of the HOZD and also we can see the lower amplitude anticline and syncline developed to the east and beneath the shelf. As was pointed out earlier, there are complicating, additional smaller folds developed within these structures. These will show up in the structure

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map which will be shown in a later figure. The main point to make here again is that the faulting that occurs in the folded section east of the HOZD is a function of squeezing of the beds by the gentle folding of these very incompetent, and impermeable beds which develops high pore pressure and results in faulting and buckling along the crests of the folds. Most of the displayed faults are intra-formational and relatively minor and do not extend from deep in the section to the surface. In many places we can trace reflectors across the tops of the folds. In most places, we cannot extend these faults up into the younger Monterey shown in blue.

Let us move on to the NEKTON profiles (Fig. 19) further to the south,and we will see that the broad anticline-syncline pair that we have been tracking from the north to the south will project into the uppermost of the NEKTON lines. Before discussing the NEKTON sections, I would like to point out that these are of a different scale than the Woodward-Clyde lines. These are a different type of seismic profile and were shot at a higher repetition rate. As a result, they have a vertical scale exaggeration which averages only about 3 to 1. The water-gun device, as used, allows clearer definition of thin layers and minor structures. It does not get deep penetration, but was designed to identify deformation and faulting in the upper two hundred meters of the stratigraphic section.

With the NEKTON survey we were attempting to look in this southern region for any possible extension of the Cristianitos fault and particularly for evidence as to whether or not it might interconnect with the HOZD. In the uppermost profile, we see the typical development of Offshore Zone of Deformation. Also evident are the folds of the anticlinesyncline pair projecting from the

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north. The feature has become distinctly narrower here, appears to be dying out and, at the level of line 26, becomes more parallel to the HOZD as it extends to the southeast. This will be seen better on the plan view structure map to be shown later. The projection of the anticline-syncline from the Woodward-Clyde data into the NEKTON data is best seen in NEKTON lines 30 and 28. Figure 20 shows a detail of that part of line 30 that contains the fold. The new, narrower and somewhat steeper-sided fold does not appear to be faulted. Spurious "crossover" type reflections are developed on the deeper flanks of the fold. These are the result of the inability of the relatively broad beam of the receiving system to define abrupt changes in slope where the strata on the flanks of the anticline are flexed in their change to a synclinal configuration.

South of NEKTON line 24 there is a rather striking change in the seismic reflection expression of the HOZD. The HOZD is no longer expressed as a very large, complex, faulted anticline, but appears to show well bedded Monterey-type reflectors juxtaposed by a single fault against a very fuzzy and incoherent zone of poor reflectors. Such fuzziness is very reminiscent of the type of records obtained from traverses over known San Onofre Breccia-type rocks. You will note that we have not put interpreted line drawings in the lower three of these profiles. Because of the change in geology, good reflecting horizons are difficult to see. The structures may be there, but they are very difficult to recognize. Furthermore, we are well south of the region of a possible intersection of the HOZD and Cristianitos. We do see a juxtaposition of the bedded, Monterey-type sediments against the homogeneous section without coherent reflectors. Note that at the level of line 22 the syncline flanking the east side of the HOZD has disappeared. This expression

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of the HOZD is seen on the four southern profiles from the NEKTON data. The position of this single HOZD fault can be seen on the lower three profiles of the NEKTON data posted on the wall (Fig. 19).

A feature that should be noted is that, as the anticline-syncline folds that we tracked from north to south dies out, a second zone of folds develops to the east. These in turn become less prominent further south and become gentle, very broad folds.

The upper colored units are the same as those similarly colored in the Woodward-Clyde lines to the north. No Plio-Pleistocene unit can be traced this far south and only a very thin green, Capistrano equivalent unit is present in the upper three profiles. Even the blue, youngest Monterey unit is missing on the lower three sections. The prominent unconformity between the blue and the older Monterey below and the onlapping of the blue over the older sediments again shows that most of the folding had developed prior to deposition of the latest Monterey. That unit was, however, deposited as the less intense folding of that time took place.

To summarize what we have seen in these sections, the main structures are the HOZD and the very prominent syncline that lies on its eastern flank. In the central part of the surveyed area, the other main features we see are the anticline-syncline folds which trend north northwest, diverging from the HOZD

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in the area of the Woodward-Clyde data, and dying out to the north. These same features are more parallel to the HOZD in the northern part of the NEKTON data area. Further south they disappear. These folds have associated faults with an axial development. Other folding and associated faults are developed to the east in the area covered by NEKTON lines 26, 28, and 30.

Fig. 21 is the composite structural map resulting from this work. The structural map shows all of the features that are displayed within the data sections, including the folds and the faults, both in the shallow and deeper parts of the recorded section. Because the map displays all of the folds and faults from all depths, it is cluttered with data. To sort out this plethora of data, the various elements should be considered separately.

If we look first at the trends of the major fold axes, we can see that the most prominent and continuous feature is the major syncline that lies to the east of the HOZD. The folded zone to the east of the HOZD comprising the broad anticline-syncline pair is also well displayed. It is apparent that these folds converge with the HOZD in the region of the Woodward-Clyde lines in the northern area and then become parallel to it in the NEKTON data area to the south. These folds also die out to the north and south, being best developed in the central Woodward-Clyde data area. The folds still further to the east in the area of the juncture of the two survey areas are well shown on this map.

Next we will strip away the folds and look at a series of maps showing faults of different ages. Figure 22 shows the oldest faulting that occurs largely in San Onofre Breccia. These faults are seen only in the northwestern area.

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There are probably similar faults further to the south, but they were not detected in the profiling. Where they are recorded, the San Onofre Breccia is shallow enough to have been picked up by the geophysical techniques used. Faults that occur in the older Monterey are seen in the next map (Fig. 23). These faults are best exposed in the central portion of the area where they are coincident with the development of the anticline and syncline pair. Faults of this age pick up again to the east in the NEKTON data to the south. Displacement on these faults is very difficult to determine because one does not see clear offsets of the reflectors or horizons. Displacement is probably from a few meters to a few tens of meters.

The next map (Fig. 24) shows faults that occur in the blue, upper Monterey unit. We see it only in the northern fold area east of the HOZD where we see faults penetrating to the upper Monterey. These faults do not cut the Capistrano formation and are therefore at least four million years old.

Our final map (Fig. 25) shows faults that extend to the sea floor or the Pleistocene unconformity. They are confined within the HOZD.

To summarize once again, the seismic data does not reveal a seaward extension of the Cristianitos fault beyond about six thousand feet. Faults east of the HOZD are of two types. They are either very old faults deep within the section that cut the San Onofre Breccia and do not extend very far up through the older Monterey section, or they are types of faults that result from deformation associated with folding. These appear to be interformational faults generated by the folding of the sediments. The seismic data does not show these faults extending deep into the section nor to the Pleistocene unconformity and their apparent zonal distribution is a function of their association with the broad folds east of the HOZD.

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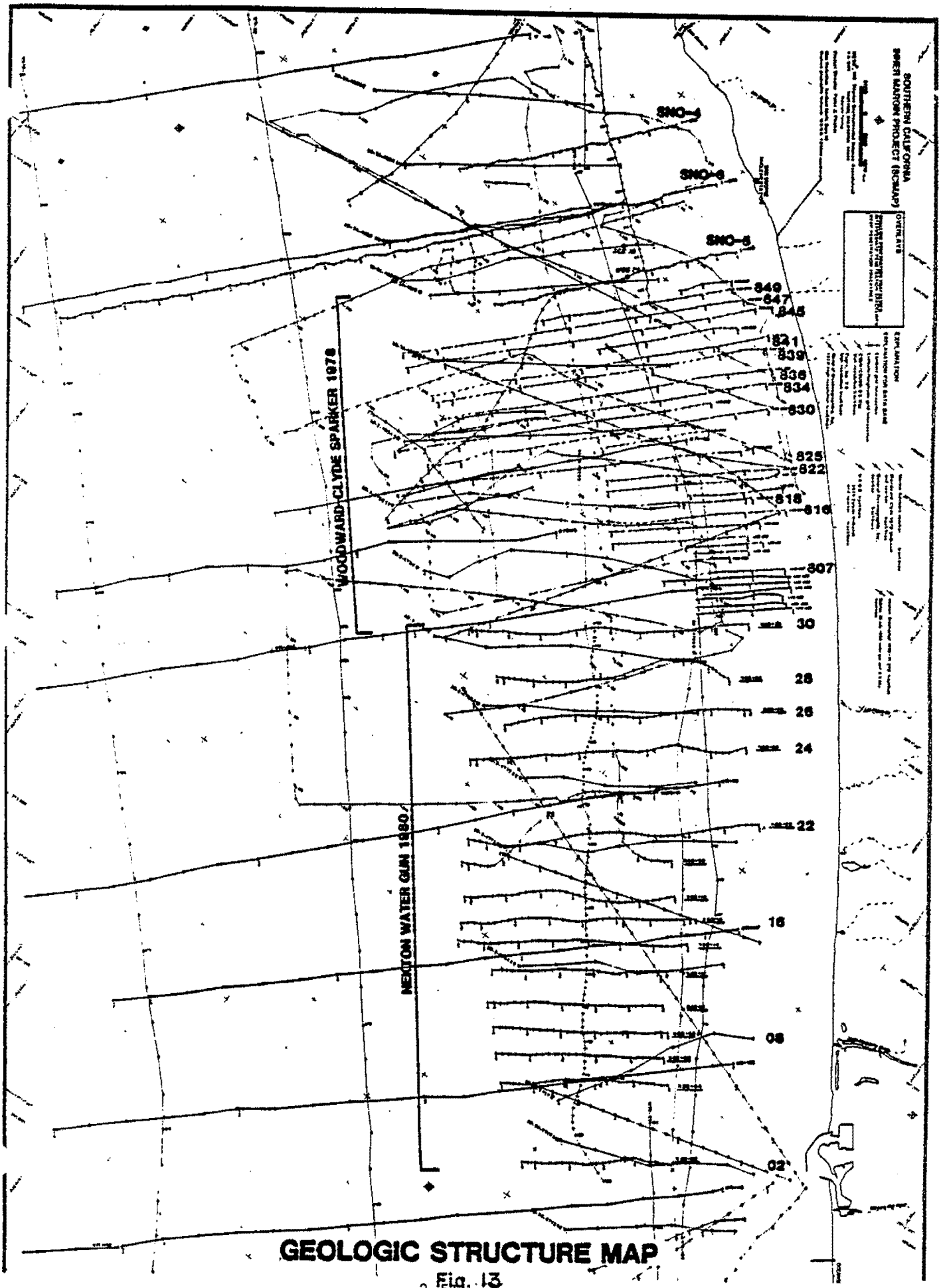
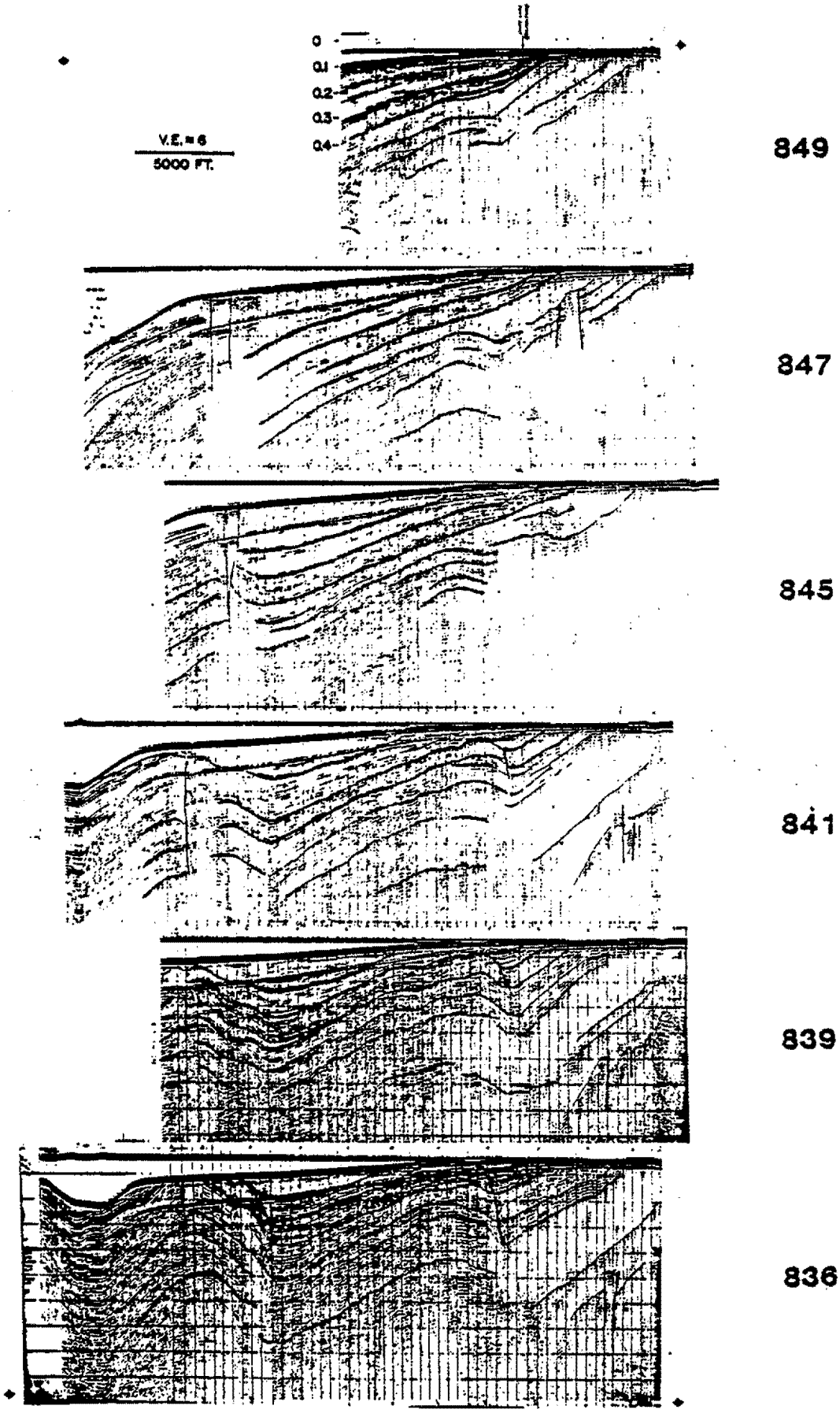


GEOLOGIC STRUCTURE MAP

Fig. 13



WOODWARD-CLYDE SPARKER 1978

Fig. 14

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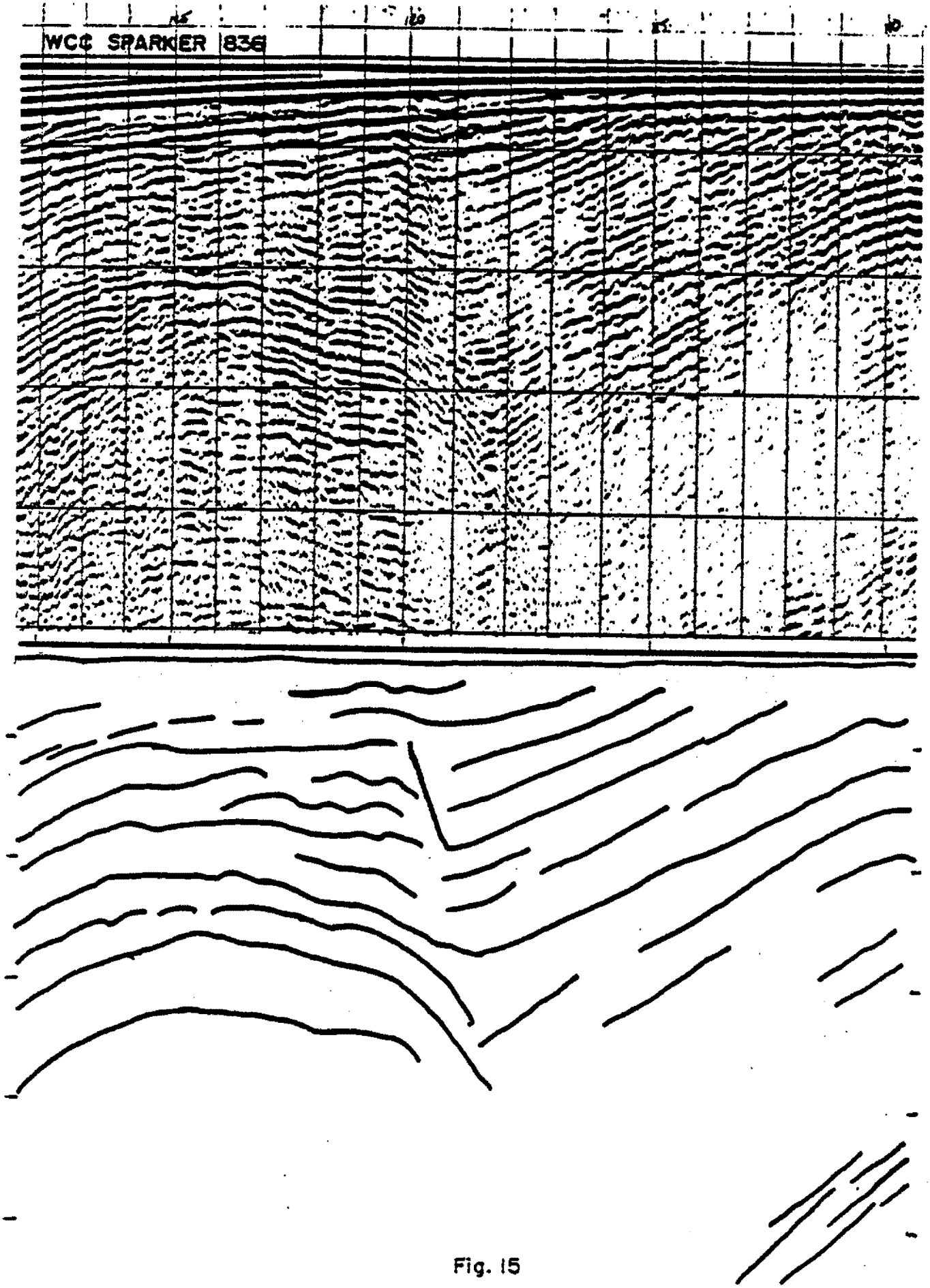

Fig. 15

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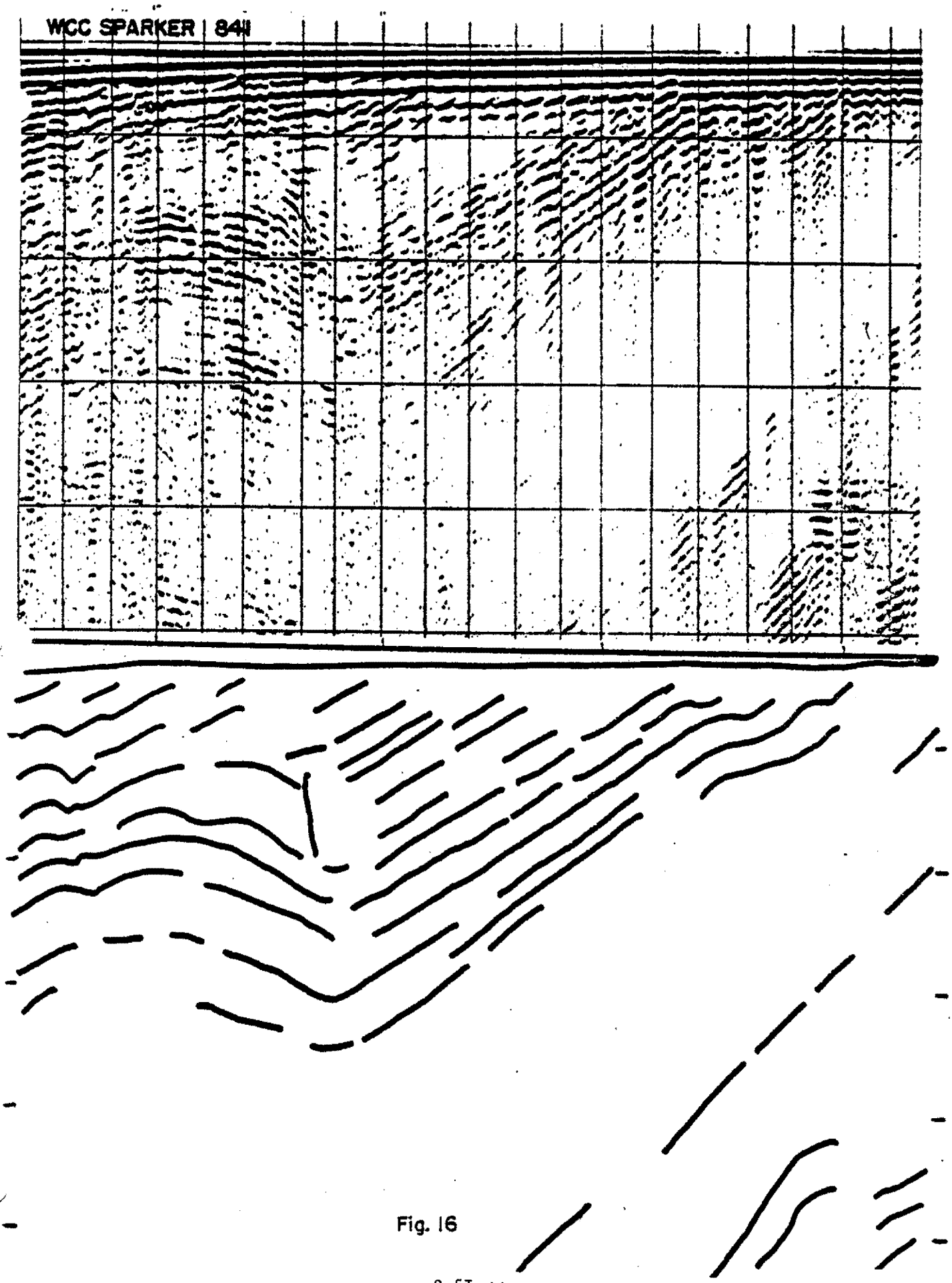
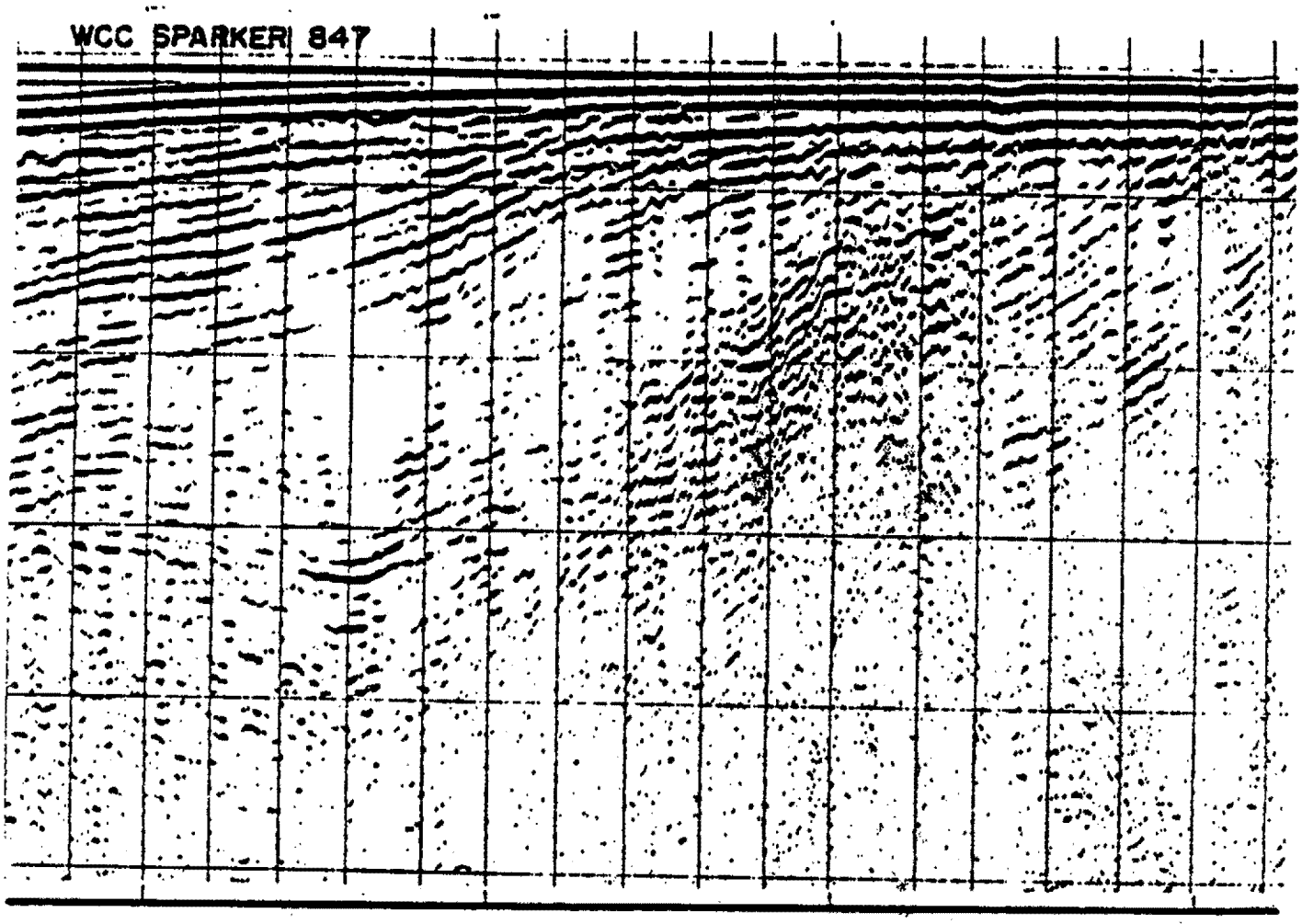


Fig. 16



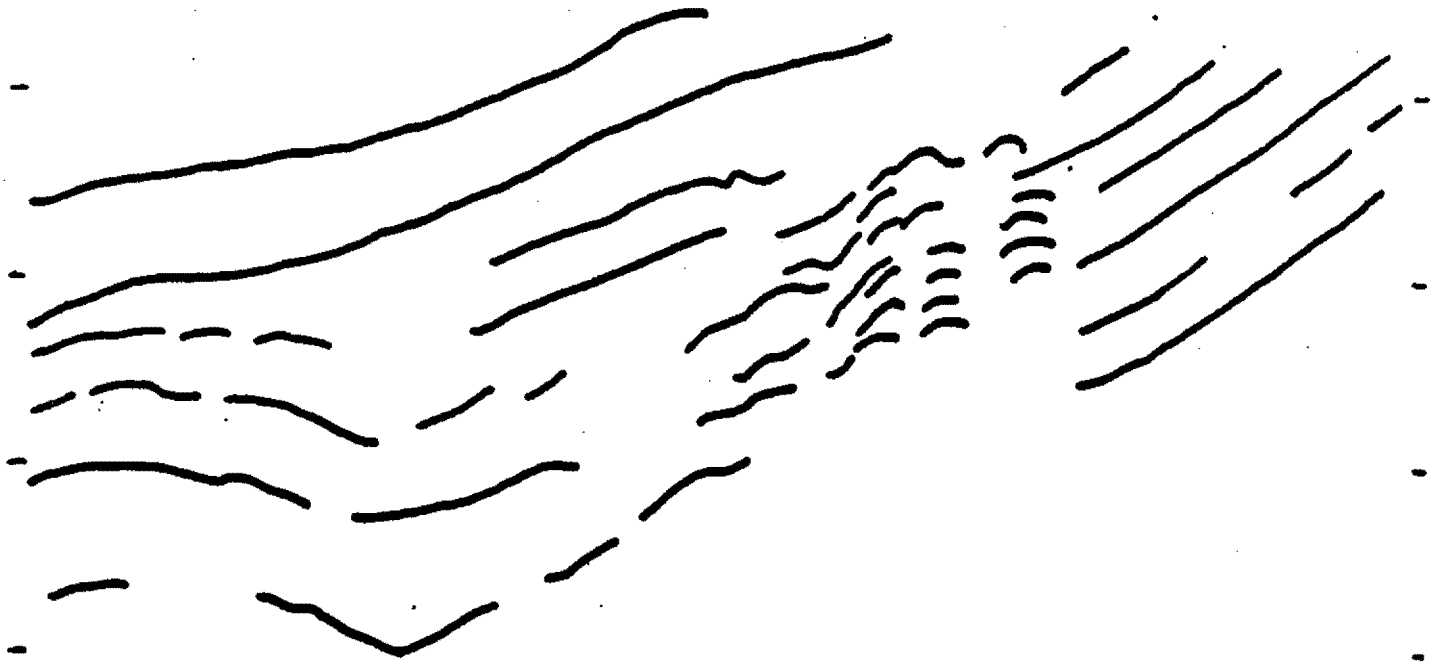


Fig. 17

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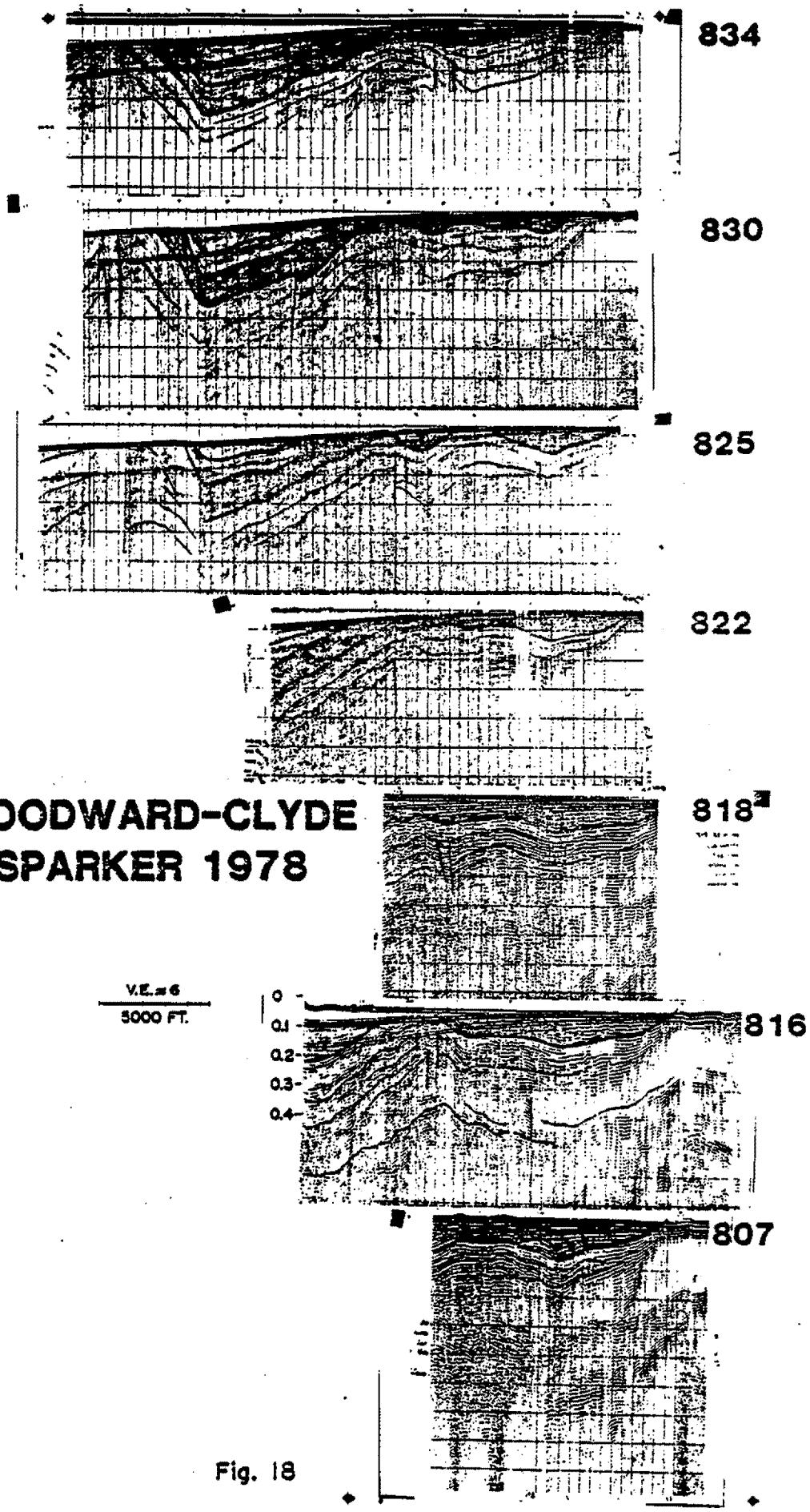

Fig. 18

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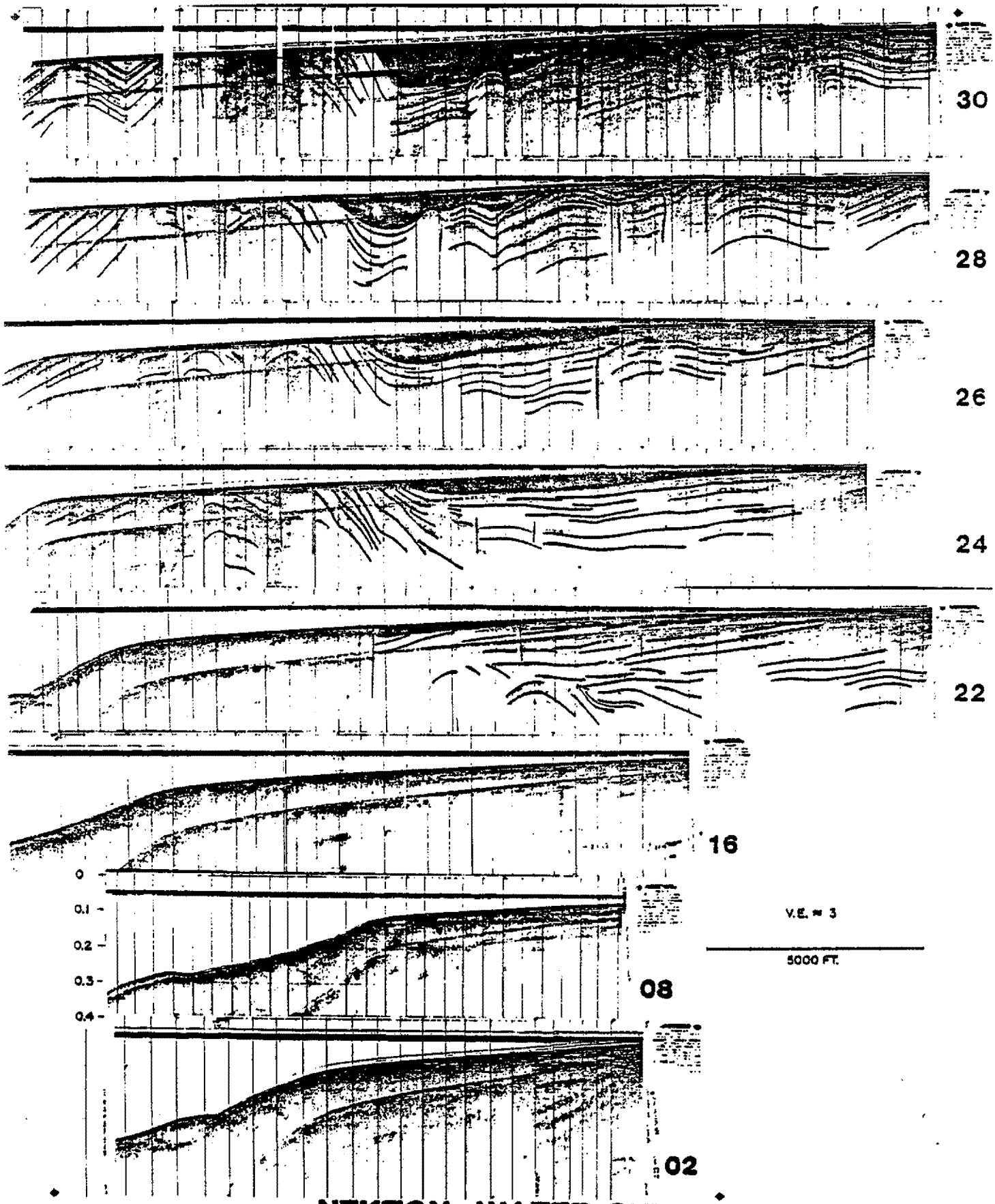
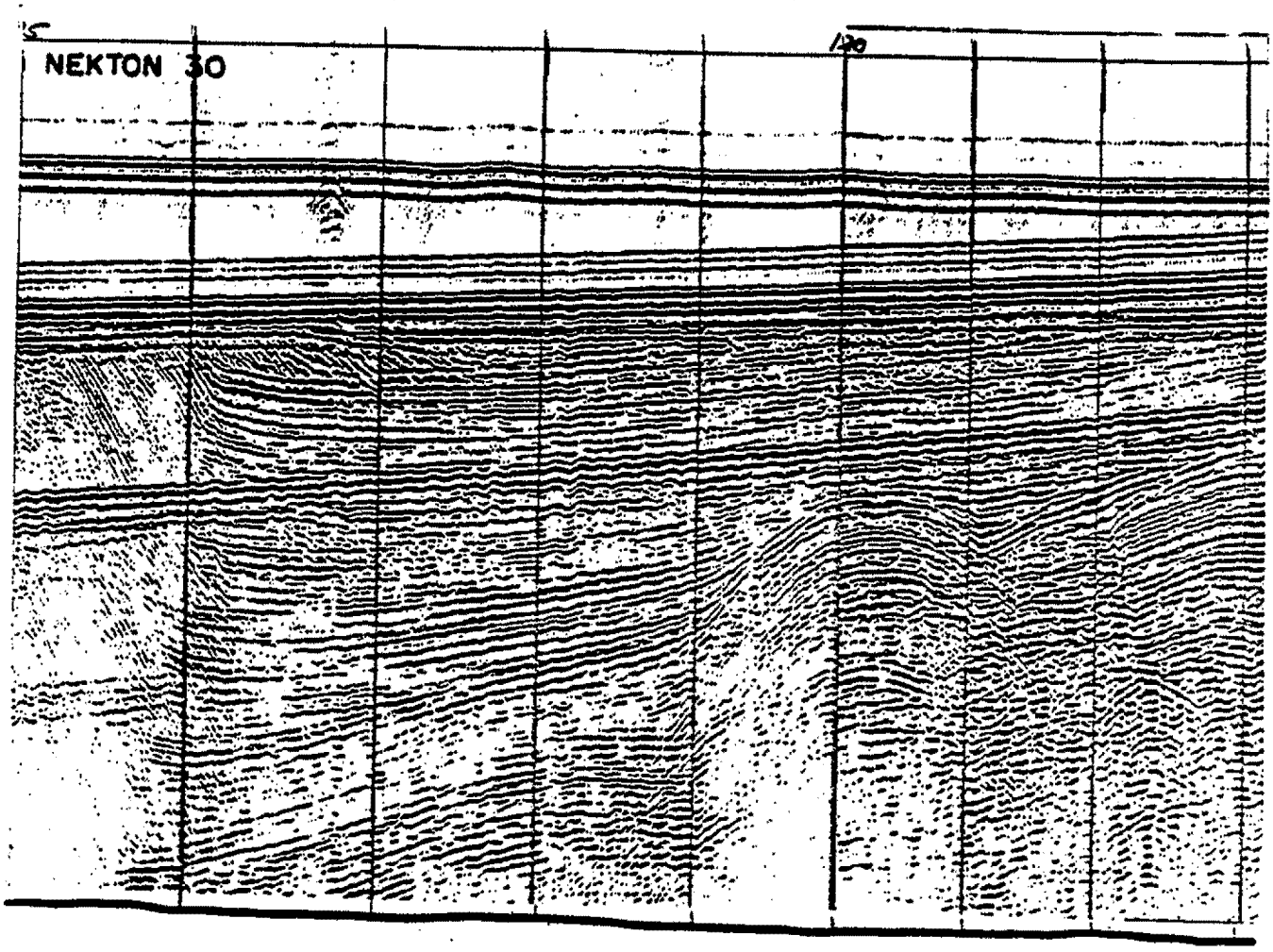


NEKTON WATER GUN 1980

Fig. 19
2.5I-44



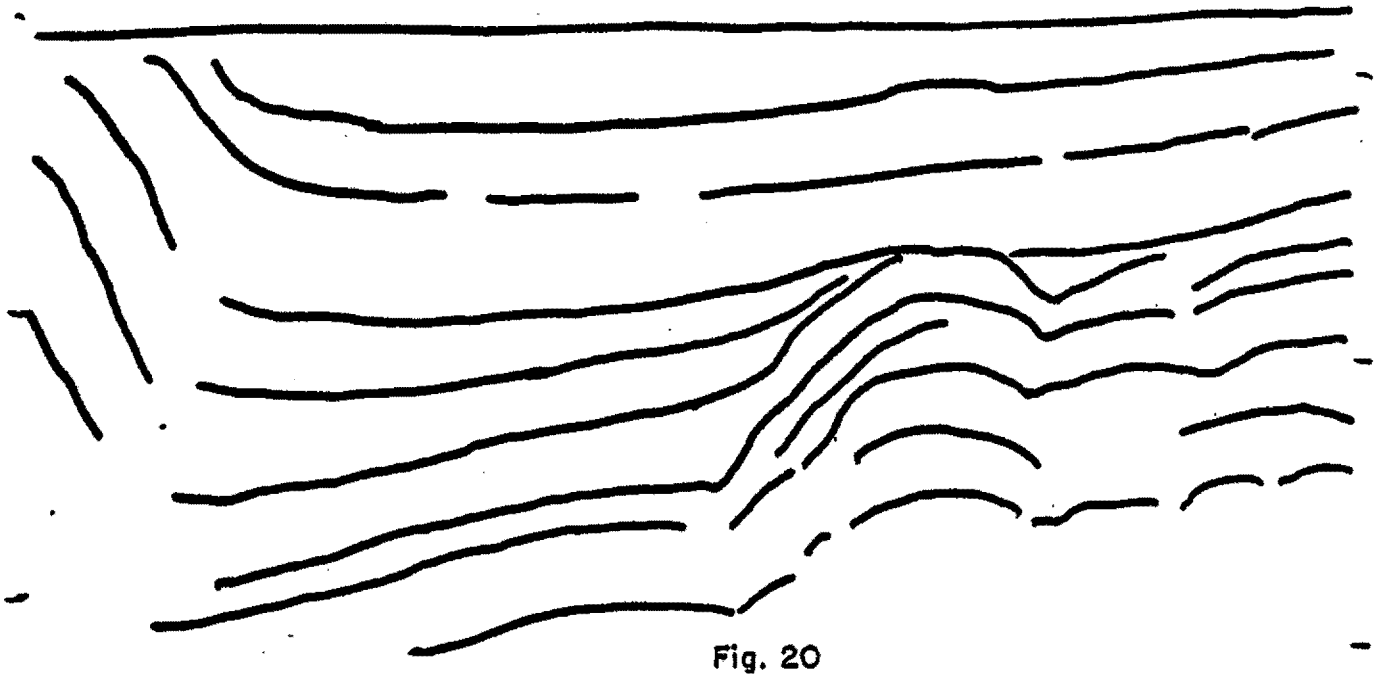


Fig. 20

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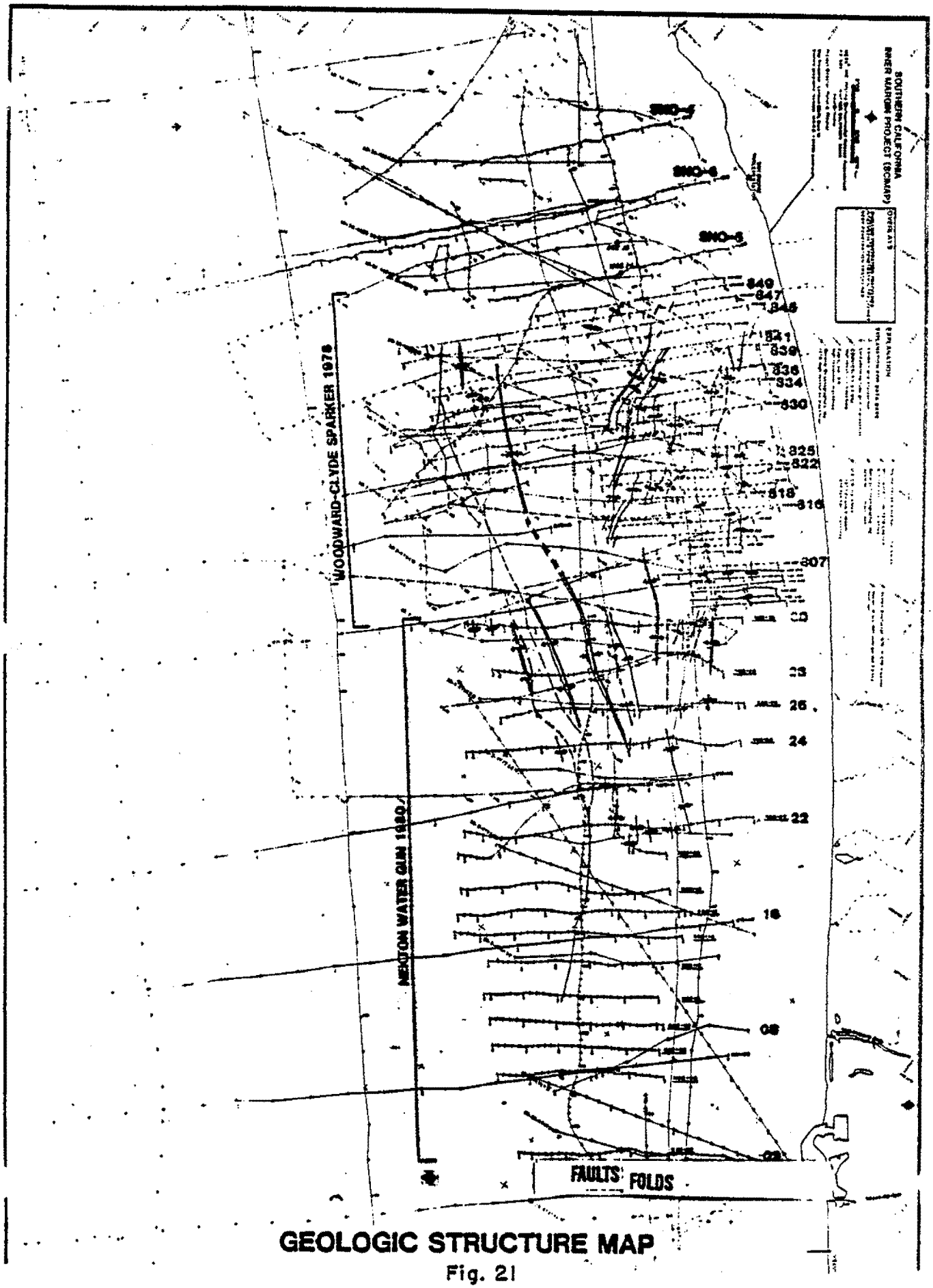
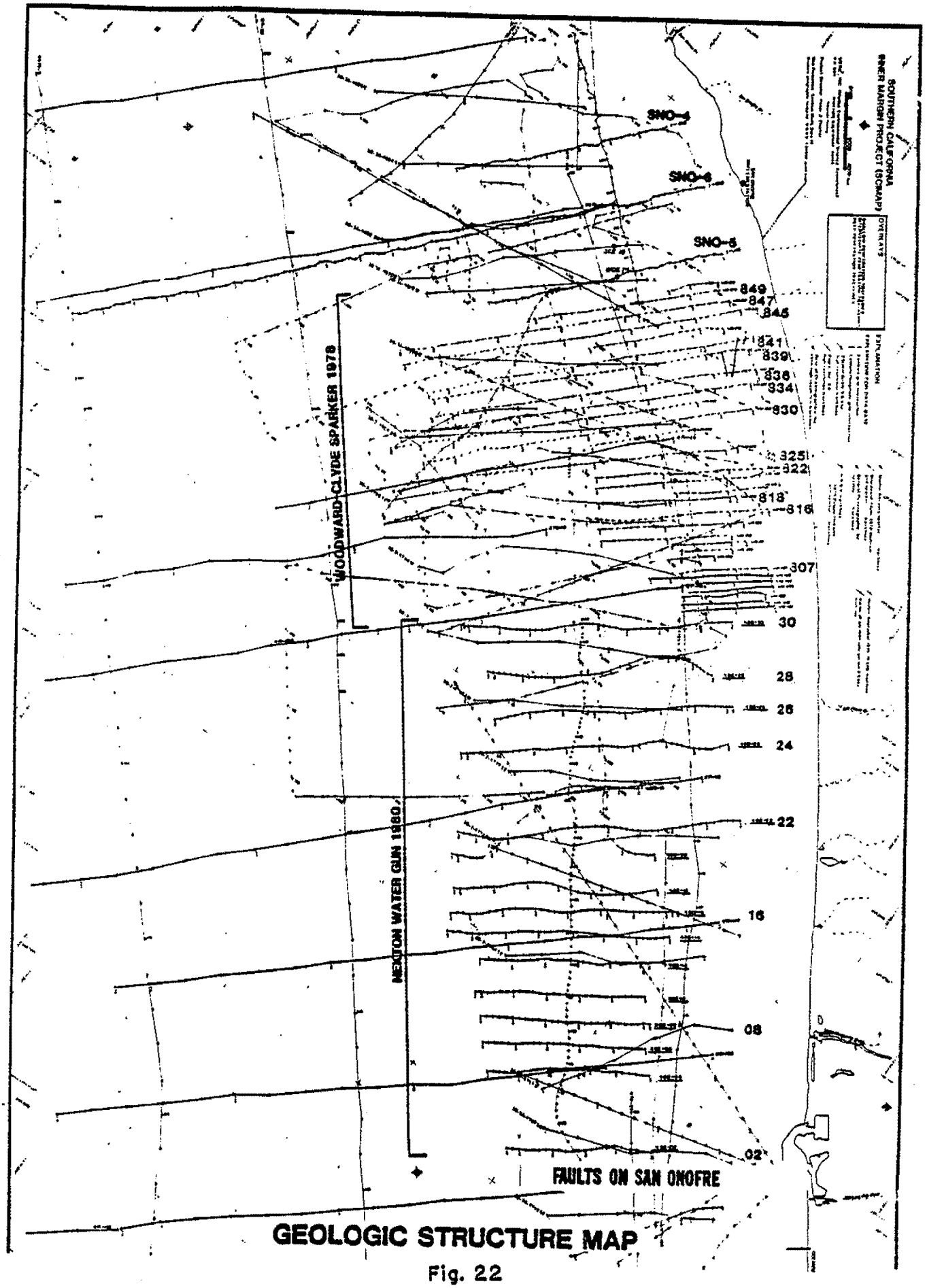


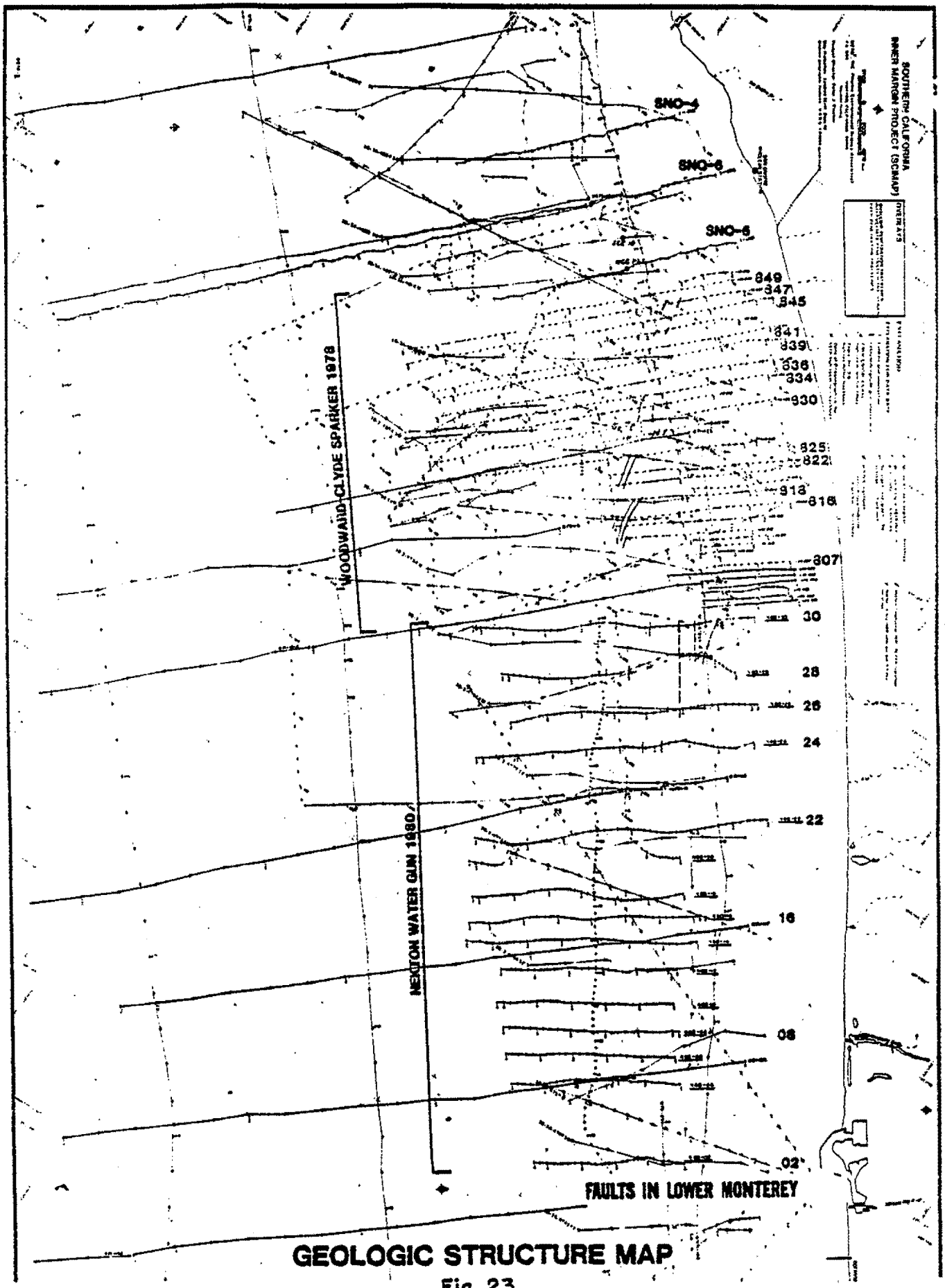
GEOLOGIC STRUCTURE MAP

Fig. 21



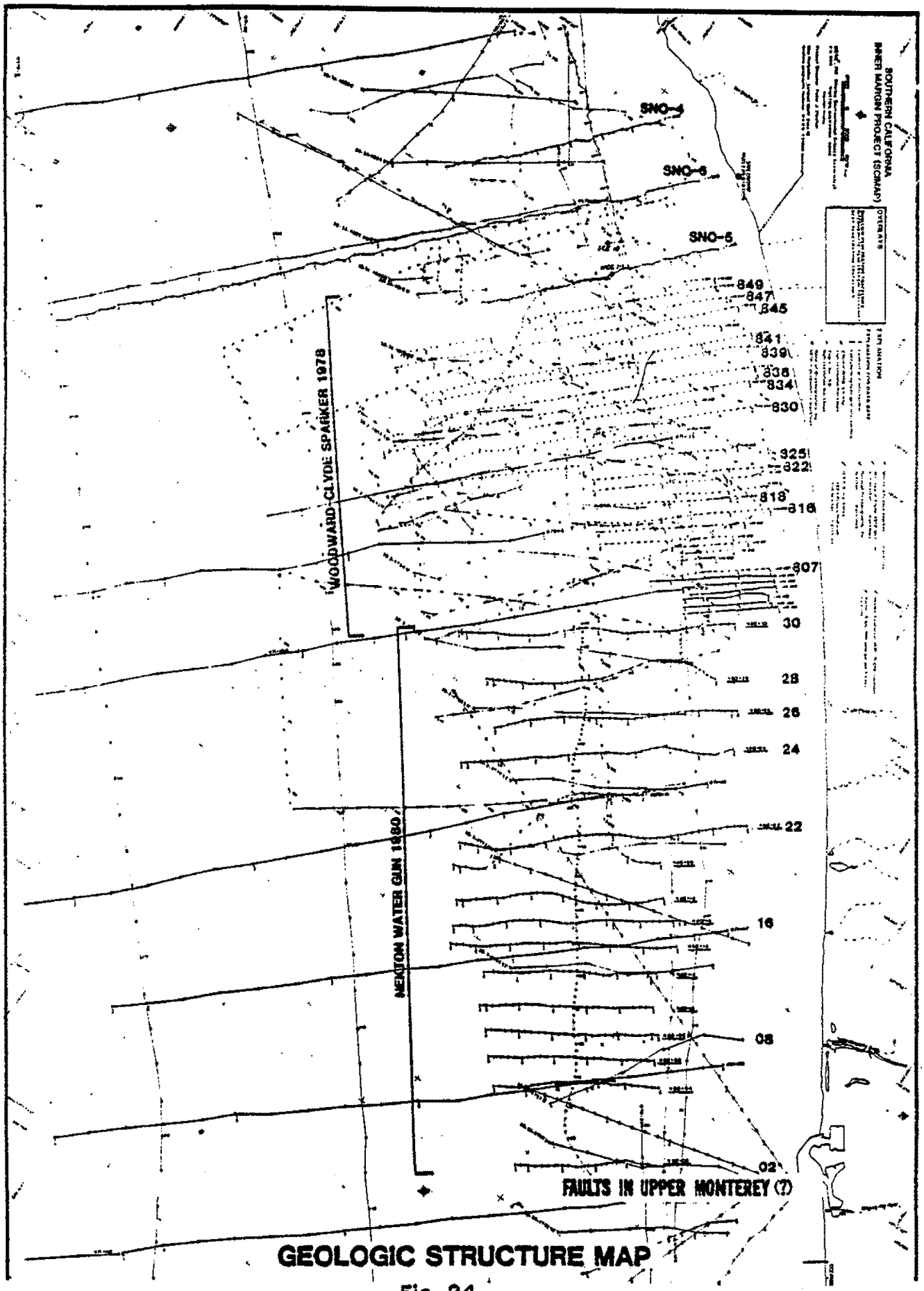
GEOLOGIC STRUCTURE MAP

Fig. 22



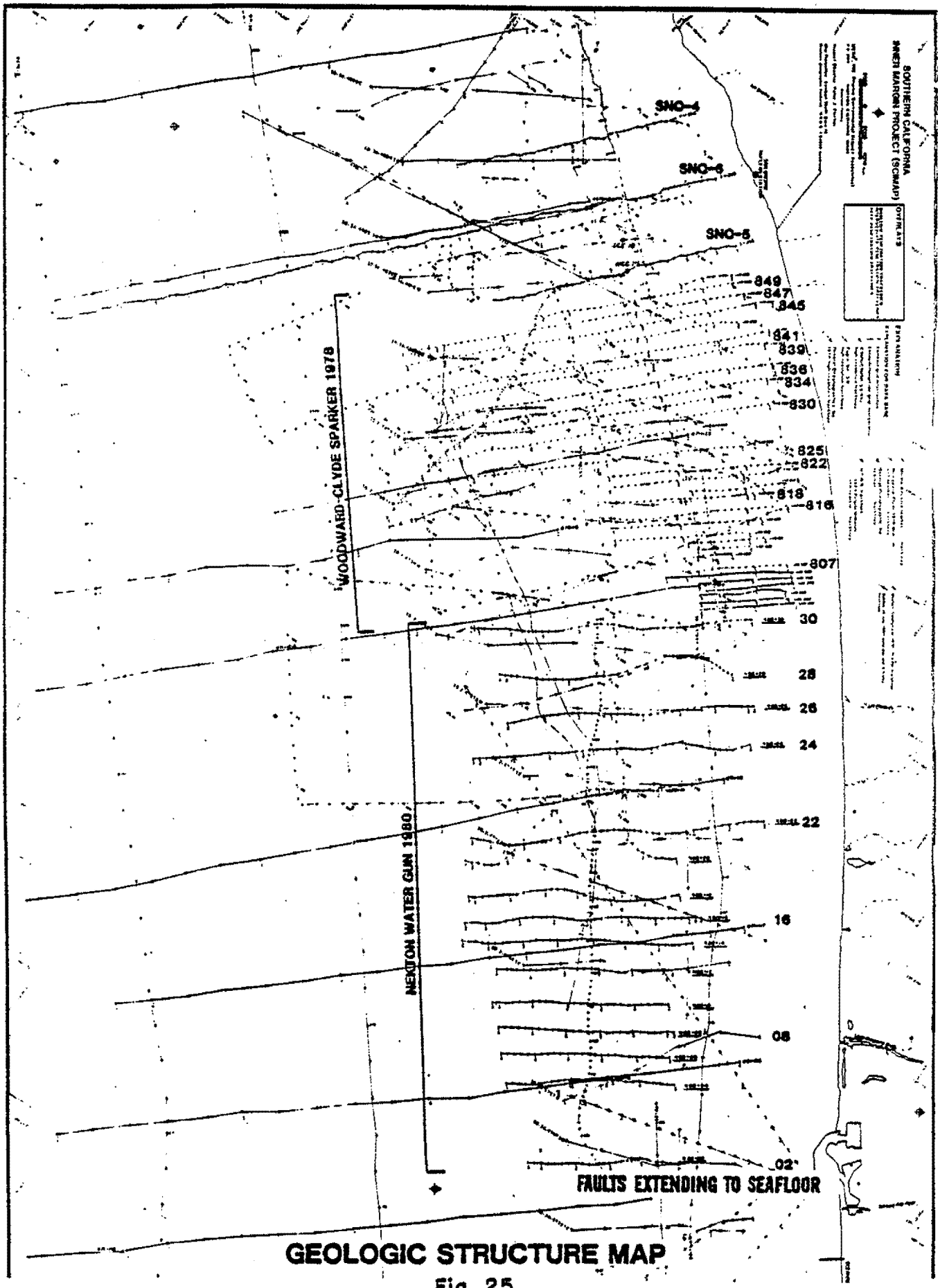
GEOLOGIC STRUCTURE MAP

Fig. 23



GEOLOGIC STRUCTURE MAP

Fig. 24



GEOLOGIC STRUCTURE MAP

Fig. 25

ENCLOSURE 3

A, B, C AND D FEATURES

The purpose of this enclosure is to document the relationship between the A, B, C, and D features and the present tectonic framework for the San Onofre area. The A, B, C, and D features are minor non-tectonic features which were carefully mapped and analyzed as reported in "Analysis of Geological Features at the San Onofre Nuclear Generating Station", Fugro, Inc., July, 1974 and "Final Report on Geologic features at the San Onofre Nuclear Generating Station", Fugro, Inc., August, 1976.

The current, regional stress field at depth in the Southern California area is oriented with the maximum (N-S) and intermediate (E-W) stress axes lying in the horizontal plane while the minimum stress axis is vertical. This is supported by:

1. Local mechanisms determined for local events;
2. The regional uplift along the Peninsular Ranges and, locally, the Southern California Coast; and,
3. The regional north-south compression and crustal shortening observed within the region south of the Transverse Ranges. Such an arrangement is characterized, in part, by vertical movement.

By contrast, the features described by Fugro (1974, 1976) display no vertical movement; rather, only horizontal conjugate movement. Such movement is more consistent with both the maximum and minimum stress axes oriented horizontally while the intermediate axis is vertical.

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These joints responded to local conditions such as unloading due to erosion, and configuration of the sandstone body and therefore have no regional significance.

These features clearly pre-date the stage 5e deposition which is at least 125,000 yrs. old. These features post-date the deposition of the Pliocene-age San Mateo formation. Therefore, these features are at least 125,000 years old and may be sold as several million years.

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ENCLOSURE 5

Trail Five Landslide
San Onofre State Beach

October 2, 1980

A landslide was reported by the California Division of Mines and Geology in a letter to the Nuclear Regulatory Commission, dated August 12, 1980 and signed by Mr. James F. Davis, State Geologist California Division of Mines and Geology. The location described in the letter was inspected to determine the origin of the offset gravelbed exposed in the barranca and seen on the walls. Trail 5 is located about 1800 ft. south by Unit 1 containment structure. The location of the inspection is shown on Figures 1 and 2.

The feature described in the August 12 letter is about 120 ft. downstream of the stairways at Trail Five, San Onofre State Beach. The feature is seen on the east barranca wall; exposed in the lower 15 ft. of the approximately 75 ft. high cliffs. The sediments have been mapped by an SCE geologist as a unconsolidated, weakly cemented Quaternary non-marine deposits consisting of silty and clayey sand interspersed with lenticular gravel and cobble beds. Surface run-off typically cuts deep, steeply sided barrancas's into these sediments.

The canyon was inspected and a geologic profile drawn from observations and photographs taken at the location. The exposures disclosed a gravelbed within the Quaternary non-marine sediments that is down dropped along dip about 2 ft. The down dropped block is about 10 ft. wide and extends from the barranca bottom up to about 14 ft. above the canyon floor. Close inspection of the slide surface identified small plant rootlets growing along the surface and

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accumulations of caliche which had precipitated on the sediments. The gravelbed can be recognized on the upstream side and can be traced beyond the downdrop block to the downstream side. An illustration of the slide and gravelbed is shown in Figure 3.

A relatively thin block of Quaternary soil slabbed off the barranca wall and a gravel bed within the slab was downdropped about 2 ft. down dip (18 inches vertically). The extent of this soil fall is limited to the rock shown on Figure 3. It is concluded that the offset bed is a landslide. This landslide is due to undercutting by stream erosion and weakening of Quaternary deposits comprising the canyon walls.

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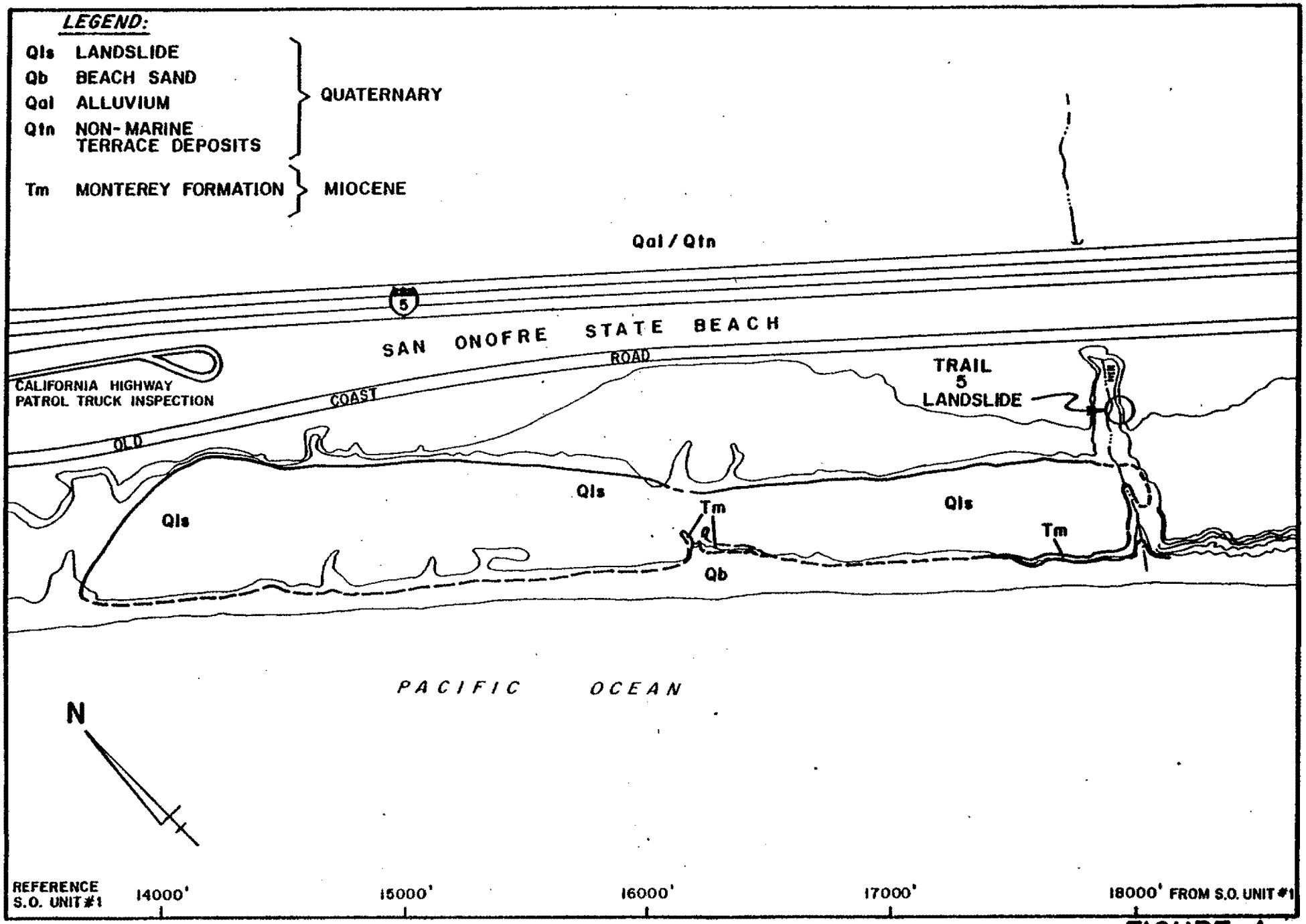
LEGEND:
Qls LANDSLIDE
Qb BEACH SAND
Qal ALLUVIUM
Qtn NON-MARINE TERRACE DEPOSITS
QUATERNARY
Tm MONTEREY FORMATION
MIOCENE
Qal / Qtn
5
SAN ONOFRE STATE BEACH
OLD COAST ROAD
CALIFORNIA HIGHWAY PATROL TRUCK INSPECTION
TRAIL 5 LANDSLIDE
Qls
Tm
Qb
PACIFIC OCEAN
N
REFERENCE S.O. UNIT #1
14000'
15000'
16000'
17000'
18000' FROM S.O. UNIT #1

FIGURE 1

TRAIL 5 LANDSLIDE SAN ONOFRE STATE BEACH

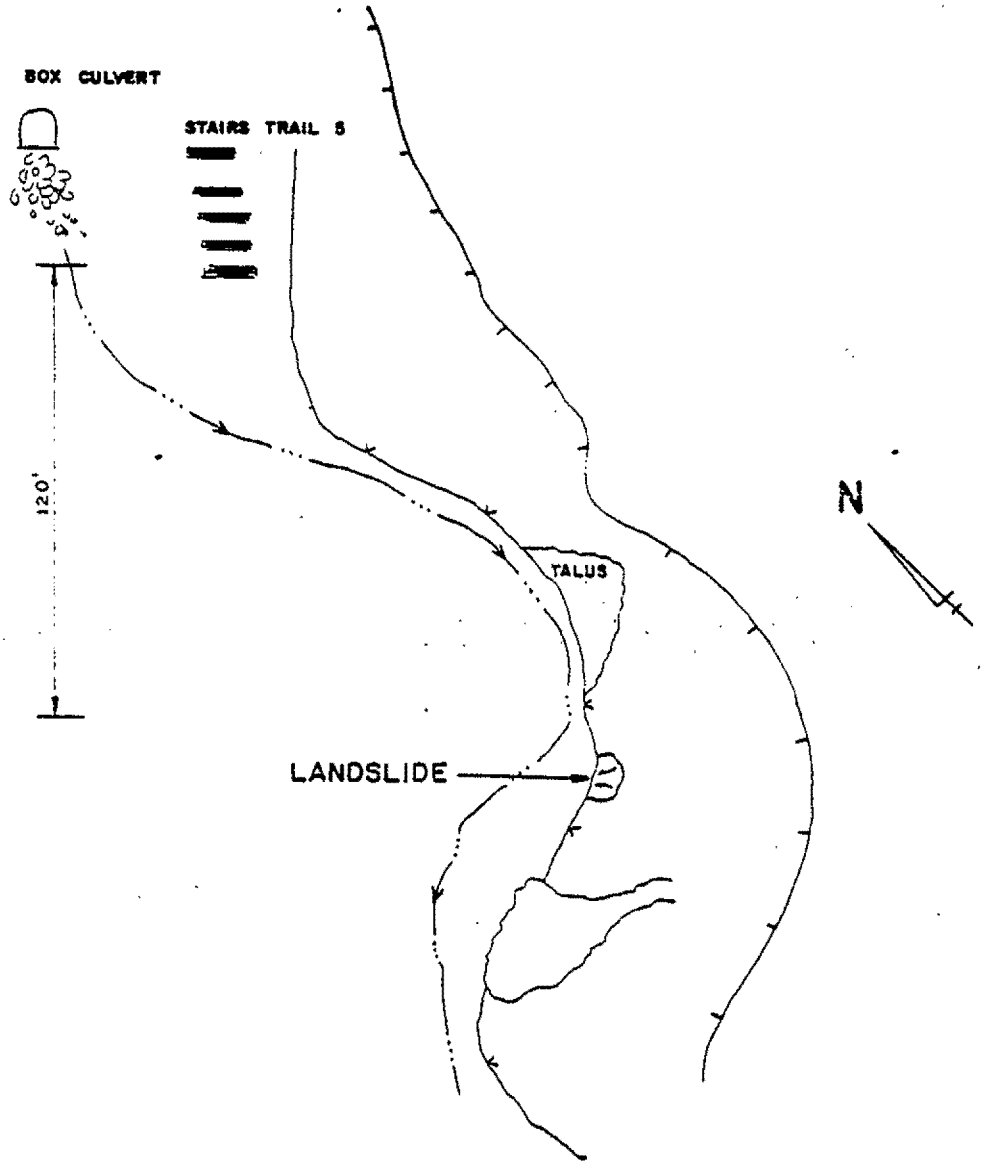

FIGURE 2

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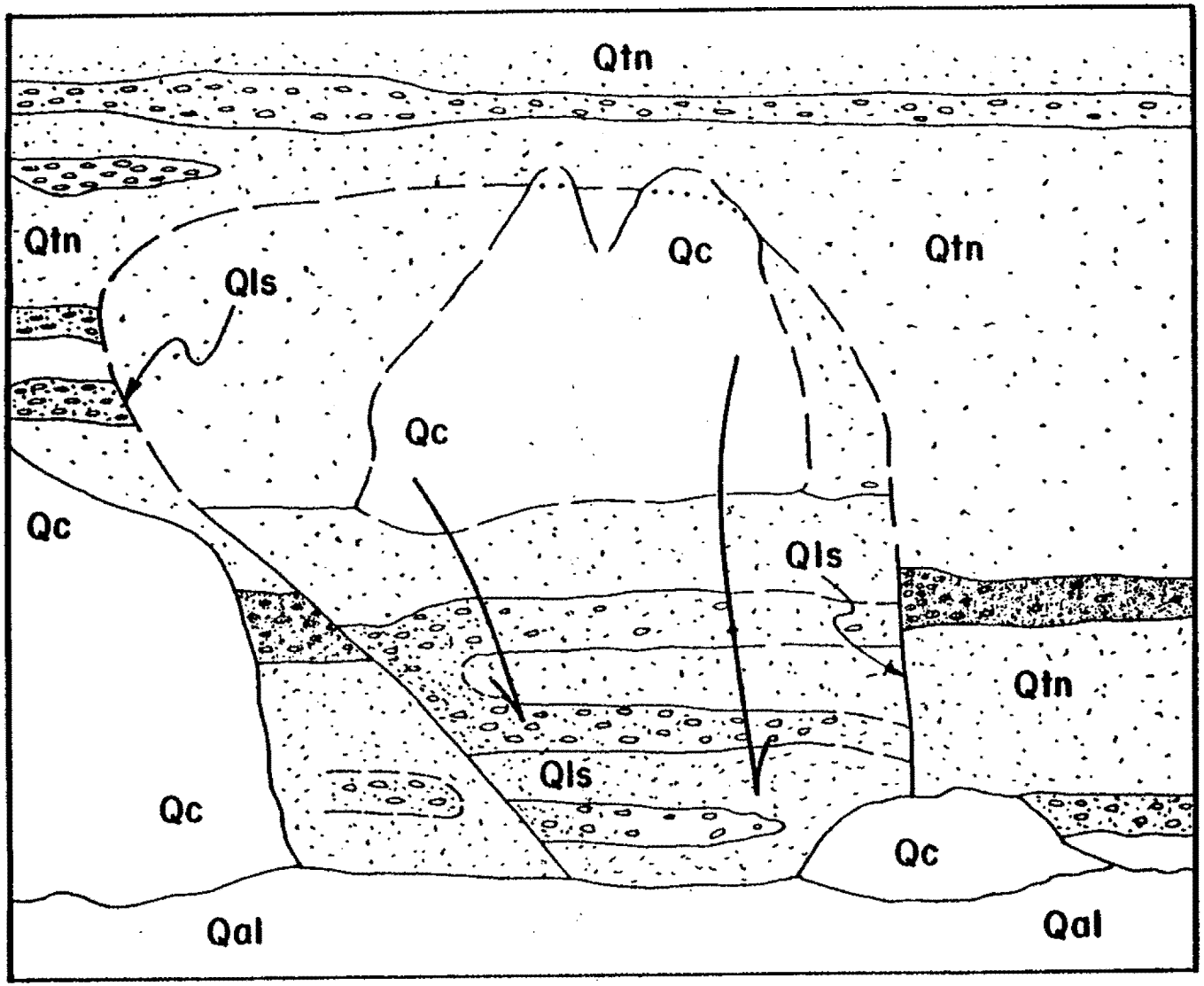

CROSS-SECTION TRAIL 5 LANDSLIDE, SAN ONOFRE STATE BEACH

NO SCALE

SEPTEMBER 1980

FIGURE 3

Edited Transcript of Dr. Roy J. Shlemon

Quaternary History of the San Onofre Area

Presentation to NRC/USGS - September 23, 1980

Menlo Park, California

The purpose of this presentation is to relate the Cristianitos Fault to the Quaternary geology and geomorphology of the San Onofre area; particularly with reference to a now-dated terrace and sea level chronology, both onshore and offshore. This presentation has three major objectives:

> First, to briefly review the late Quaternary geologic and geomorphologic framework of the area. Second, to relate the late Quaternary geological history to tectonics of the San Onofre area, based mainly on marine terrace chronology, and compare this with coastal terrain elsewhere in southern California. And third, to note the probable ages of offshore terraces described by preceding speakers and illustrated in various profiles for the Cristianitos Fault area.

With respect to the Quaternary geologic history of the San Onofre area, I call your attention to the now well-known marine isotope stage chronology useful to date coastal marine terraces and related deposits, independent of any radiometric dates that may be available. Shown on this viewgraph (Fig. 1), are relative changes of glacio-eustatic sea level over the last 1,000,000 years. Since publication of this paper, there have been some

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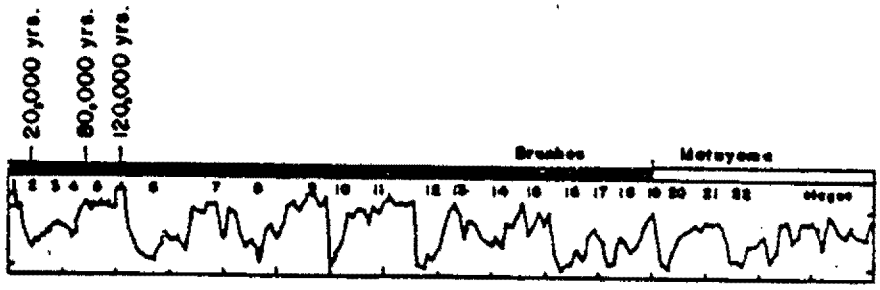

Fig. 6. Relative change in sea level in Middle and Late Pleistocene time, based on oxygen isotope composition of foraminifera in a mid-Pacific core (after Shackleton and Opdyke, 1973, p. 48). Late Pleistocene boundary from oxygen isotope substage 5a (ca. 130,000 years BP) to present, Middle Pleistocene from Brunhes/Matuyama magnetic reversal (ca. 700,000 years BP) to substage 5e.

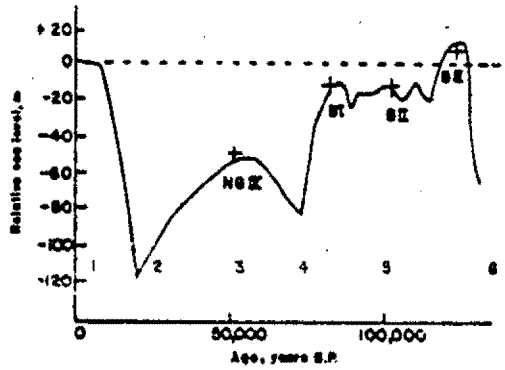

Fig. 7. Glacio-eustatic sea level curve for the past 130,000 years derived from oxygen isotope measurements in mid-Pacific core compared with dated terrace corals from Barbados (BI, BII, BIII, Broecker, and others 1968) and New Guinea (NGIII, Veeh and Chappell, 1970). Curve from Shackleton and Opdyke (1973, p. 45).

APPENDIX 2.5I
FIGURE 1

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refinements to the chronology. These changes, however, are minor, and essentially the broad framework indicated here remains the same.

First, with respect to the upper diagram, the dark line indicates the Brunhes/Matuyama paleomagnetic boundary, approximately 700,000 years b.p. Relative high and low stands of sea level are indicated by the curves. The odd numbers refer to relative high stands of sea level; for example, 3, 5, 7, 9, 11, etc., whereas, the even numbers refer to relative low stands of sea level (glacial-eustatic); e.g., 2, 4, 6, 8, etc.

Of particular importance to the San Onofre area are marine isotope stages 5, 4, 3, and 2 (lower diagram). Isotope substage 5e, shown on both the upper diagram, and the enlarged lower diagram (Figure 1), is especially significant. It is part of stage 5 (80,000 - 125,000 years b.p.). During substage 5e time, about 125,000 years ago, sea level appears to have been above the present, perhaps the only time during the last 700,000 years. The 5e shoreline, measured in tectonically stable places of the world, was on the order of about 6 to 10 m above present, and therefore, serves as a stratigraphic marker to compare uplift rates regionally.

Isotope stage 4 (Fig. 1) is essentially equivalent to the early Wisconsinan of the classical midcontinental chronology, about

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60,000 to 70,000 years ago. Isotope stage 3 is mid-Wisconsinan, about 35,000 to 40,000 years ago; and substage 5a, is about 80,000 years BP (Fig. 1). All of isotope stage 5 is frequently termed "late Sangamonian."

Isotope stage 2 is generally equivalent to the last major low stand of sea level (late Wisconsinan), a level about 100 m below the present. Sea level rose to its present elevation (Flandrian trangression) about 5,000 years ago.

Of interest to the San Onofre area is isotope stage 5, especially substage 5e, because onshore terrace deposits of that age overlie the Cristianitos Fault. Isotope stages 3 and substage 5a are also of some interest, because submarine platforms of these ages now appear to have been located offshore.

The onshore terrace chronology and Quaternary geology at San Onofre is presented in this viewgraph (Fig. 2), taken from a report submitted a few years ago (Shlemon, 1978). In brief, locality No. 1, is the first onshore terrace at San Onofre. The other numbers refer to marine terraces and respective shoreline-angle elevations here indicated in feet. The highest terrace is about 1,250 feet. All these terraces, their continental covering deposits, and shoreline-angle elevations, were mapped by Dr. Perry Ehlig (1977).

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MARINE TERRACE DEPOSITS

COMPOSITE SECTION, REPRESENTATIVE ELEVATIONS AND APPROXIMATE AGES
SAN ONOFRE STATE BEACH AND CAMP PENDLETON, CALIFORNIA

[Terrace deposits designated on potentially by number in circle; inferred age (years BP) shown in brackets]

NOTES

1. Section line bearing N 40° E; coastal intersection approximately 4 miles SE of San Onofre Unit 1.
2. Terrace deposits, mainly beach gravels, after Ehlig (1977); contour interval 25 feet; supplementary contours 5 feet.
3. Terrace elevation and gravel thickness composite, projected from outcrops between Station 19,000 and 22,000 of Ehlig (1977, Fig. 7). Distance (in feet) and direction of outcrop from section line shown above terrace number.
4. Terrace topography generalized; surface of San Onofre Bluffs from SCE base map, scale 1:6,000.
5. Thickness of Terrace 1 deposits extrapolated from measured section in "Haul Road Canyon" (Station 35,500 of Ehlig, 1977); see text for discussion.
6. Age of Terrace 1 deposits interpreted from amino-acid dating (Lajoie and others, 1975); older deposits from inferred association with late Quaternary high stands of sea level, deduced from oxygen isotope and paleomagnetic stratigraphy of deep sea cores (Shackleton and Opdyke, 1972, 1976); see text for discussion.

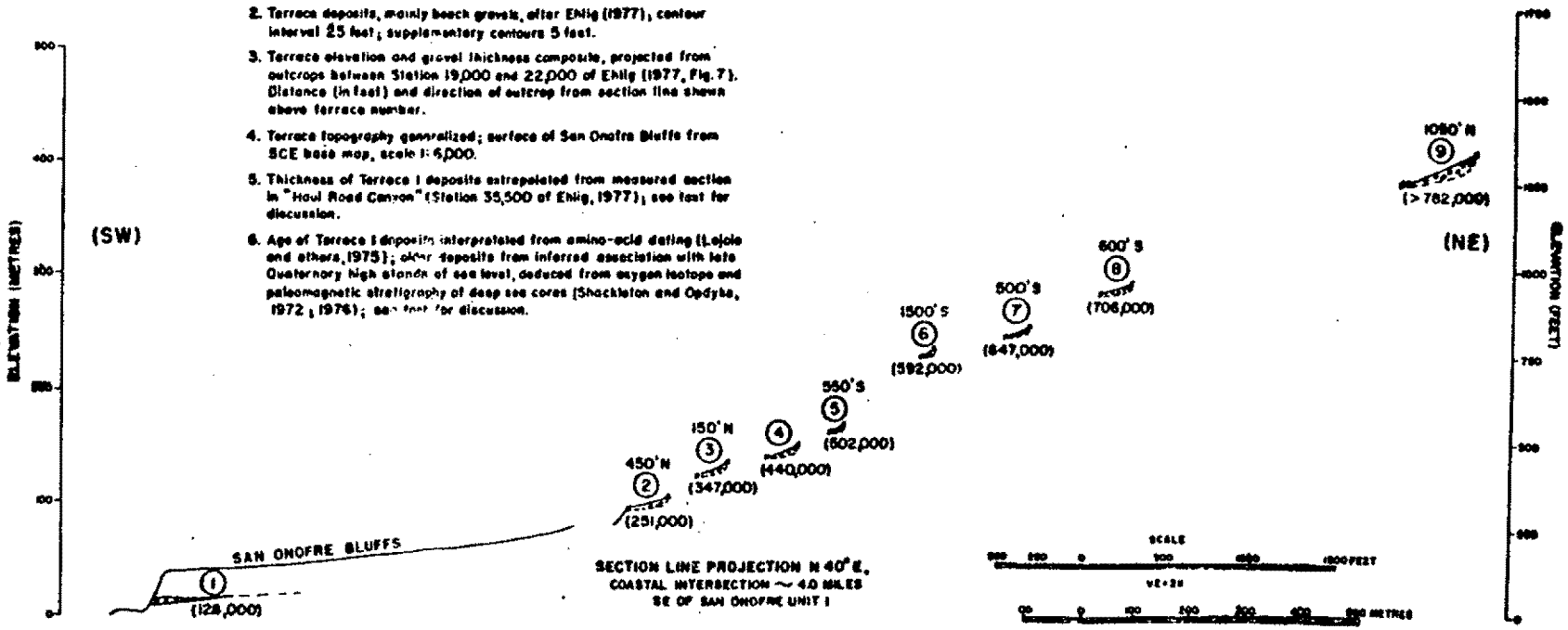

FIGURE 2

APPENDIX 2.5I
FIGURE 2

Only the first marine terrace deposit and wave-cut platform at San Onofre is dated radiometrically. However, several dating methods corroborate the ages assigned. First, there is relative dating based on faunal associations. The fossils found in the first terrace deposits are of a warm water association (substage 5e), describe by Kennedy and Lajoie (USGS, Menlo Park). Second, amino-acid dates are also available from comparable terraces south of San Onofre. Third, laterally continuous deposits have been dated by uranium-series methods (Richard Ku, Univ. Southern California). Fourth, the age of the first terrace has also been determined by relative dating techniques. These include calculating averaging sedimentation rates, and determining the age of buried paleosols within covering continental sediments. Radiocarbon dates from the San Onofre and adjacent areas likewise date the younger sediments.

The age of the higher San Onofre terraces (Fig. 2) is based mainly on association with glacio-eustatic changes of sea level (Figure 1). As yet, there are no absolute dates for the higher terraces. However, by assuming that each terrace was cut by a trangressing sea, in turn superimposed on a tectonically rising block, it appears that the high surfaces can be dated as pertaining to isotope stages 7, 9, 11, etc; that is, in the order of about 200,000, 360,000, 470,000 etc., years b.p. (Fig. 2). The

highest terraces are presumably more than 700,000 or 800,000 years old, and these ages are probably conservative for the following reasons:

First, there are some gaps in the terrace sequences (Fig. 2). For example, about 1,000 feet above sea level there may have been a terrace, now since eroded (Fig. 2). Second, there is a major gap between the first and second terraces; and hence it appears probable that at least one and possibly even two shoreline-angles are here buried beneath some 100 feet or more of continental sediments (Fig. 2). It thus seems quite plausible that the ages assigned to each of these onshore sequences may be in fact one or two isotope ages too young.

In sum, there are at least nine terraces at San Onofre, as noted on Figure 2, and there may be two or more additional platforms now either eroded or buried. The ages of these terraces range in age from the well-dated 125,000 year old, substage 5e (first terrace) to well over 780,000 years and possibly older. The highest surfaces may be more than a million years old.

The next question: "What is the significance of this chronology with respect to the relative tectonic stability of the San Onofre area?" Relative rates of uplift, for 15 to 20 km on either side of San Onofre, are calculated based on approximate elevations of the substage 5e shoreline angle (Table 2) [There is <u>no</u> Table 1,

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Table 2

Average Uplift Rate of Terrace 1 for the Last 125,000 Years (Stage 5e level) Between Laguna Beach (North) and Target Canyon, Camp Pendleton (South)

Locality	Measured or Projected Shoreline Angle Elevation (ft)	(m)	Uplift Rate (cm/1000 years) Original Shoreline Elevatio +6 m	+10 m
Target Canyon/Camp Pendleton	42	13.0	6	2
San Onofre South	57	17.7	9	6
San Clemente State Beach South	66-68	20.8	12	9
San Clemente State Beach North	68-70	21.4	12	9
San Clemente Pier South	97	30.1	19	16
San Clemente Pier North	83	25.7	16	13
North San Clemente #3	90	27.9	18	14
North San Clemente #2	97	30.1	19	16
North San Clemente #1	116	35.9	24	21
Capistrano Beach	100	31.0	20	17
Dana Point	125-126	39.1	26	23
Niguel Beach State Park	122	37.8	25	22
South Laguna	112-114	35.0	23	20
Aliso Beach	72-74	22.6	13	10
Laguna Beach Recreation Park	30	9.3	3	-1

See text for descriptions of measured locality and projection of gradient for shoreline-angle elevation

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since these were selected from other reports.] Particular uplift rates are given for the Target Canyon area at Camp Pendleton, and for other specific localities northward to about Laguna Beach.

The uplift rates, expressed in cm/1,000 years, are shown for two assumed shoreline-angle elevations at 125,000 years b.p.; namely, at +6 and +10 m. There is a divergence of opinion as to the absolute elevation of sea level during substage 5e. For convenience and comparison, however, it is assumed that sea level about 125,000 years ago was approximately +6 m. Thus, from Table 2, we observe the tilting of coastal terrain northward from San Onofre to at least Dana Point and probably farther northward to the Laguna Beach area. The uplift rate south of San Onofre is approximately 6 cm/1,000 yrs; at San Onofre Units 2 and 3, it is about 9 cm/1,000 years; but these values increase to about 26 cm/1,000 years at Dana Point (Table 2). In fact, as observed in the almost continuous sea cliffs north of San Onofre to Dana Point, the shoreline-angle elevations appear to be rising towards the San Joaquin Hills.

The uplift rates at San Onofre for the last 125,000 years take on particular meaning when compared with other southern California localities. This is illustrated in Table 3. Here, from the literature, rates of uplift are expressed in cm/1,000 years. Three uplift rates are given for the San Onofre-Dana Point area (Table 3); viz, 9 cm and 26 cm/1,000 years, respectively; values

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APPENDIX 2.5I

Table 3

Comparison of Late Quaternary Uplift Rates
Southern California Coast *

Reference	Area	Length of Record (Thousands of Years)	Approximate Uplift Rate (cm/1000 Years)
Wehmiller et al., (1978, p. 513)	Ventura/Pitas Point	40-50	620
Wehmiller et al., (1978, p. 513)	Ventura/Pitas Point	2.5	640
Wehmiller et al., (1978, p. 513)	Ventura	80	200
Wehmiller et al., (1977, table 13)	Santa Barbara, Goleta	30-50	140
Wehmiller et al., (1977, table 13)	Cayucos	135	13
Wehmiller et al., (1977, table 13)	San Pedro (First Terrace)	120-140	18
Wehmiller et al., (1977, table 13)	Newport Beach (First Terrace)	120-140	15
Wehmiller et al., (1977, table 13)	San Diego/Pt. Loma	120	16
Wehmiller et al., (1977, table 13)	San Diego/Pt. Loma	70-90	23
Birkeland (1972 p. 441)	Malibu Coast	105	30-45
Bandy & Marincovich (1973 p. 653)	Baldwin Hills, L.A. Basin	36	500-800
Woodward & Marcus (1976, p. 128)	Rancho La Brea, L.A. Basin	100	40-50
Ku & Kern (1974 p. 1715)	San Diego Coast	120	11-14
Kern (1977 p 1563)	San Diego Coast	120	16-20
(This Report)	Dana Point	125	26
(This Report)	San Clemente	125	12-19
(This Report)	San Onofre	125	9

* San Onofre-Dana Point uplift rates calculated from sea level assumed at +6 m, ca. 125 kya.

useful for comparison with other published rates for the southern California coastal area (Table 3).

In the Ventura area, for example, late Quaternary uplift rates are quite high, typical for the southern flanks of the Transverse Ranges. At Pitas Point (Table 3), amino-acid dating of terrace deposits shows an uplift rate of some 620 cm/1,000 years; and for a Holocene terrace, the uplift rate is a calculated 640 cm/1,000 years (Table 3). These uplift rates decrease southward from the Transverse Ranges toward the Los Angeles Basin. Even here, however, a very high uplift rate has been reported; some 500 - 600 cm/1,000 in the Baldwin Hills (Table 3). This rate, however, is subject to some dispute, and has since been refuted by other investigators. The revised uplift rate is now about 40-50 cm/1,000 years. But all these rates, when compared to those at San Onofre, point to relative stability of the immediate San Onofre area for at least the last 125,000 years.

The next question: "Can we relate the onshore chronology to the offshore area at San Onofre?" This question is in part answered by reference to the diagram (Figure 3) which illustrates schematically the various onshore and offshore marine terraces and platforms, The offshore geophysical profiles show that there are at least two -- and perhaps more -- offshore platforms comparable in extent and morphology to those onshore. In review, the first onshore terrace, for comparison, is dated radiometri-

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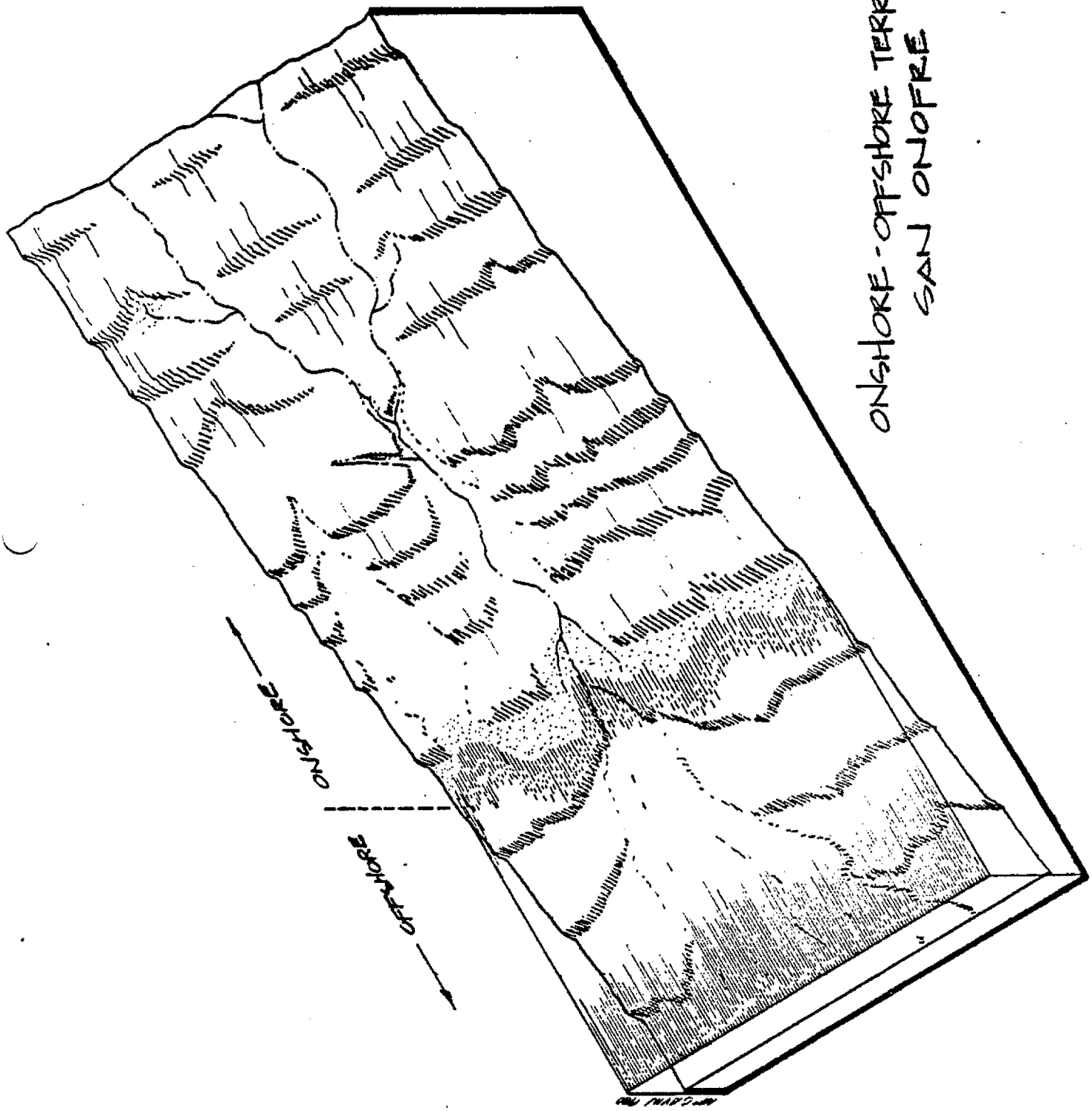

ONSHORE - OFFSHORE TERRACES
SAN ONOFRE

APPENDIX 2.5I
FIGURE 3

cally and by other techniques as pertaining to substage 5e; i.e., about 125,000 years old. The higher terraces are correspondingly older, dated by association to the marine isotope chronology.

A more detailed schematic of the onshore and offshore geomorphic relationships is shown in this diagram (Figure 4), traced from Woodward-Clyde geophysical line 849. Superimposed on this drawing are two of the five new radiocarbon dates now available for sediments covering the offshore marine platforms. These dates were obtained by Woodward-Clyde from sediments immediately offshore of the Cristianitos Fault (Table labeled 2B-1). As indicated in this viewgraph (Figure 4), the hachured line indicates bedrock. Also indicated are three offshore lines (by the symbol "X"). These particular shoreline angles can be identified not only on this geophysical line, but also on other Woodward-Clyde lines to the south over a distance of at least several kilometers. These platforms also appear on other geophysical profiles to the north toward Dana Point, and to the south toward Oceanside.

The radiocarbon date of approximately 9,500 years, shown on this diagram (Figure 4), was taken from sediments some 148 feet below sea level. This date comes from younger cover indicated on the diagram by the symbol "YC." The designation "OC" indicates older cover, also overlying the bedrock platforms (Figure 4). Another radiocarbon date of about 8,500 years was obtained from sediments

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TABLE 2B-1

SUMMARY OF AGE DATING RESULTS

Core No.	Sample No.	Depth (ft)	Material Type	Age Date in Years Before Present*
1-1	2	16.4	Shells	8,510 ± 265
1-2	6	19.7	Shells	9,095 ± 335**
1-3	14	23.4	Organic	9,400 ± 300
1-3	15	25.7	Shells	5,065 ± 180**
1-4	22	21.1	Organic	11,355 ± 650
1-5	28	30.6	Organic	13,160 ± 550
1-5	31	38.5	Organic	12,270 ± 340

* These age dates are referenced to the year A.D. 1950.

** Thorough leaching not possible during pretreatment due to limited size of sample.

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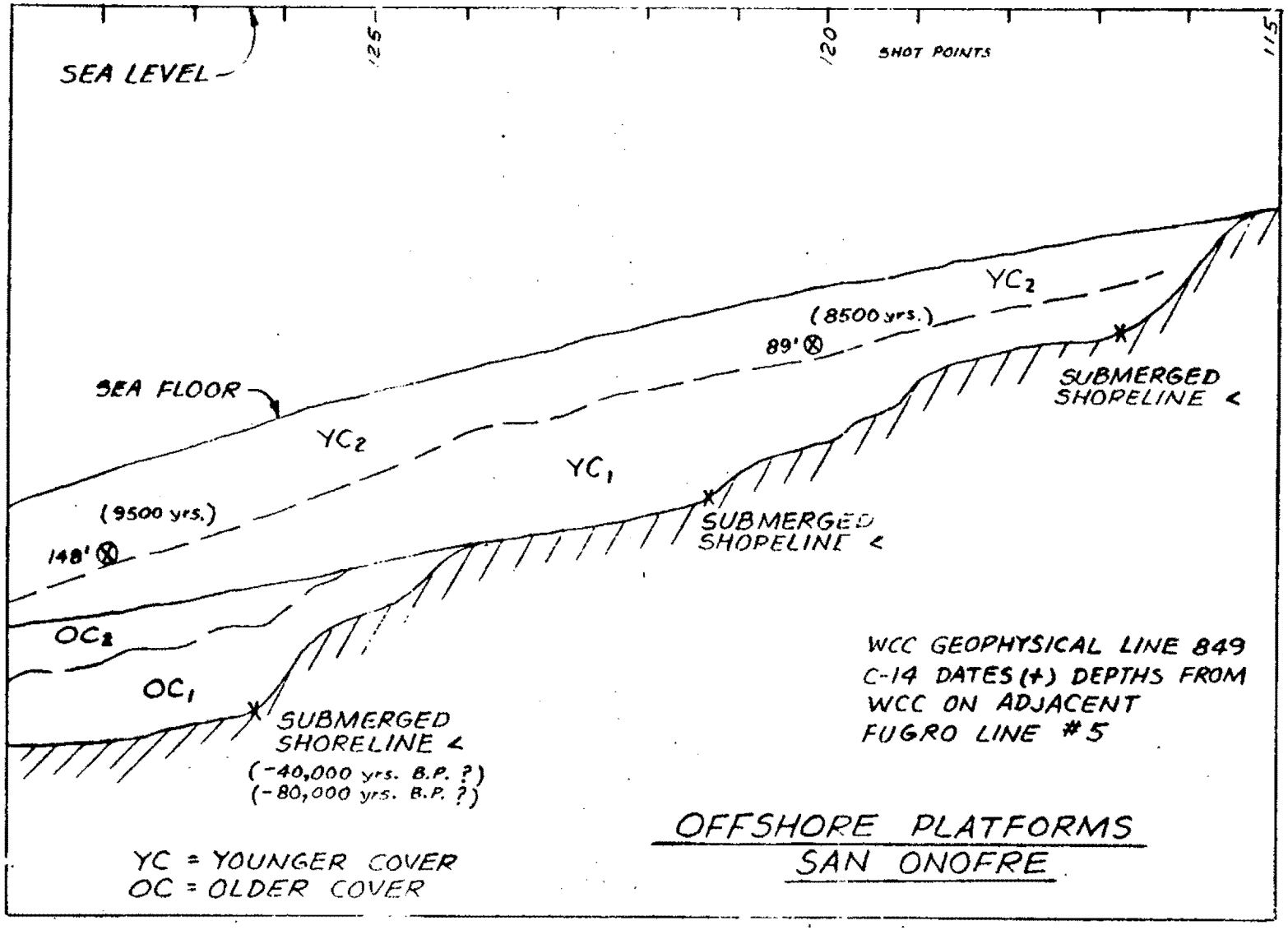

OFFSHORE PLATFORMS
SAN ONOFRE

APPENDIX 5I
FIGURE 4

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about 89 feet below sea level, also in the younger cover. Not shown on this diagram, but to the left (as you face the screen -- to the north) are two or three more radiocarbon dates from progressively older and deeper sediments. As shown in Table 2B-1, these dates are about 11,000 and 13,000 years b.p., respectively. Table 2B-1 also shows two apparently unreliable dates, for as noted by Woodward-Clyde, and by the commercial laboratory, these dates were obtained from very small samples (less than one gm), and therefore are probably contaminated. Nevertheless, there appears to be a remarkable correspondence of age and depth of sediments. The five radiocarbon dates range in age from about 8,500 to 13,000 years BP. Plotting these dates and depths on the geophysical profile (Figure 4) clearly shows that they relate to the post-glacial transgression of sea level. The dates also indicate that the older fill (OC) has been "transgressed" by younger fill (YC), and therefore was laid down before at least 13,000 years ago.

Further observable on this transparency (Figure 4) is the younger, dated fill, "graded" to the uppermost submarine platform. This platform corresponds almost exactly to where one would expect sea level to be about 5,000 years ago, based on world-wide sea level curves (Figure 1). In brief, the geophysical and radiocarbon dates indicate that offshore from San

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Onofre there are at least two distinct platforms, each covered by two younger sedimentary fills and the youngest cover is definitely post-glacial in age.

The offshore and onshore geomorphic features at San Onofre are summarized in Figure 5. Here the onshore terraces and their inferred ages (in thousands of years) are shown diagramatically. Specifically, the lowest onshore platform pertains to isotope stage 5e, dated radiometrically as about 125,00 years old. Terrace deposits of this platform continue unbroken over the Cristianitos Fault, clearly visible in sea cliffs. Shown diagrammatically also are perhaps the first data available useful to correlate the onshore and offshore geomorphic chronology. Seen here are three submerged geomorphic platforms. Based on the geophysical data and the radiocarbon dates, the upper platform was apparently cut about 5,000 years ago when sea level first reached its approximate present position. The absolute ages of the two lower platforms are presently unknown. However, based on world-wide sea level curves, it is probable that these relate to isotope stages 3, about 35,000 to 40,000 years ago; and to substage 5a, about 80,000 years ago. From late Quaternary sea-level fluctuations, it is expected that such submarine shoreline angles and related platforms should exist. Similar features have been reported elsewhere along the southern California coast. At San Onofre, the two platforms are covered by two fills, the

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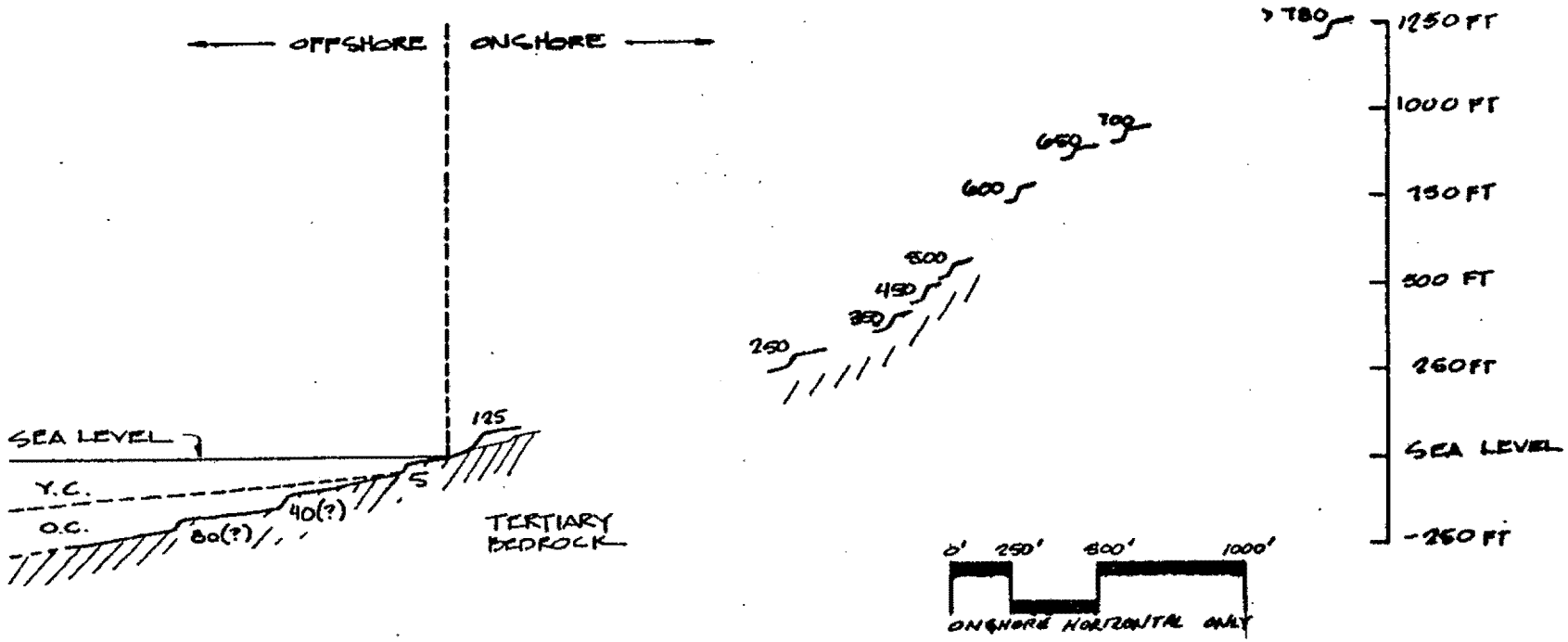

RELATIONSHIP AND AGE OF ONSHORE AND OFFSHORE PLATFORMS: SAN ONOFRE AREA

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APPENDIX 2.5I
FIGURE 5

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youngest of which is dated by radiocarbon as post-glacial; that is, post stage 2, or younger than about 17,000 - 20,000 years.

In conclusion, with respect to the late Quaternary geomorphic history in the San Onofre area, three generalized points can be made. First, onshore there exists a sequence of marine terraces (wave cut platforms) ranging in age from about 125,000 years to perhaps in excess of a million years. The marine isotope substabe 5e platform and related deposits, dated radiometrically, can be traced unbroken across the Cristianitos Fault. This particular platform is identified in almost continuous sea cliff exposures northward to Dana Point.

Second, from the new geophysical data of offshore San Onofre there are at least two sedimentary fills covering submarine platforms. The youngest cover is dated by radiocarbon as pertaining to the Flandrian transgression (post-isotope stage 2). The radiocarbon dates range from about 13,000 to 8,000 years b.p. The absolute age of the underlying, or older cover, is yet unknown. However, based on its stratigraphic position, it is older than isotope stage 2, and thus inferred to be older than about 17,000 to 20,000 years. Both of the offshore sedimentary covers are apparently not displaced by the Cristianitos Fault, as interpreted by the geophysicist.

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Third, and finally, the existence of platforms offshore of San Onofre is expectable based on world-wide, glacio-eustatic sea level changes. The absolute ages of these platforms is likewise unknown; however, from geomorphic position, and relationship to onshore terraces, they are likely associated with isotope stages 3 or 5a; that is, abot 40,000 and 80,000 years b.p. The surface upon which these platforms are cut is likewise not displaced along projections of the Cristianitos Fault. In sum, therefore, both the onshore and offshore Quaternary sequences at San Onofre show that last displacement of the Cristianitos Fault probably took place at least 125,000 years ago, and possibly long before that.

RW:mpw

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ADDENDUM TO
SUBMITTAL OF OCTOBER 6, 1980

During a presentation to the NRC staff in August, 1980, a discussion was presented concerning two onshore borings drilled to determine the amount of offset across the Cristianitos fault. Both of the borings were southeast of SONGS 2 and 3, on the alignment of El Camino Real.

Boring 1 was drilled to a depth of approximately 557 feet where it was abandoned due to caving. The second boring was located 30 feet to the west along Camino Real and was drilled to a total depth of 749.5 feet. The results of the drilling were reported in "Summary Report on Basic Data from Two Onshore and Six Offshore Geologic Borings, SONGS Units 2 and 3, San Onofre, California", dated August 4, 1980. This report presents the boring logs, description of the drilling and location of the borings.

Boring 2 will be discussed here because of the penetration through to the Cristianitos fault to San Onofre Breccia. The initial rock unit encountered was Pleistocene terrace sediments and gravel to a depth of 48 feet. From 48 feet to a depth of 444 feet, San Mateo Sandstone was encountered. Monterey formation extended from a depth of 444 feet to 669 feet where the Cristianitos fault was crossed. Below 669 feet San Onofre Breccia was encountered to the bottom of the hole.

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At the conclusion of the drilling program, a geologic profile was drawn between the 987 foot deep onsite boring drilled by Dames and Moore and these borings. See Plates 1 and 2, Enclosure 6.

Measurement of the stratigraphic separation on this profile illustrates that there is an offset of approximately 550 feet between the base of the Monterey formation on the west side of the Cristianitos fault compared to the contact exposed in outcrop on the east side of the fault.

The stratigraphic separation found in the boring supports the decrease in vertical separation along the strike of the Cristianitos fault. The maximum separation to the north decreases from about 4000 feet inland to about 50 feet vertical separation found in these borings.

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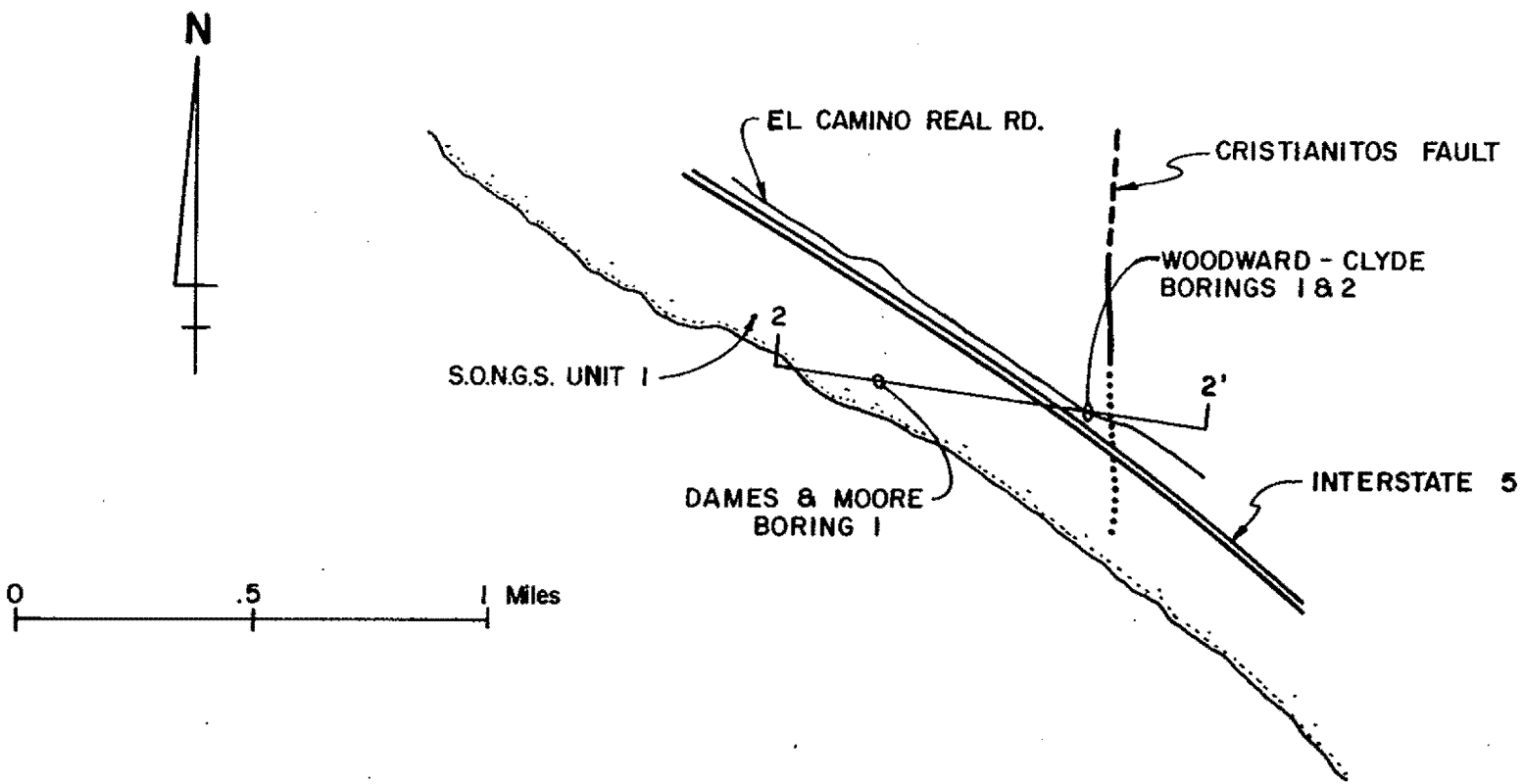
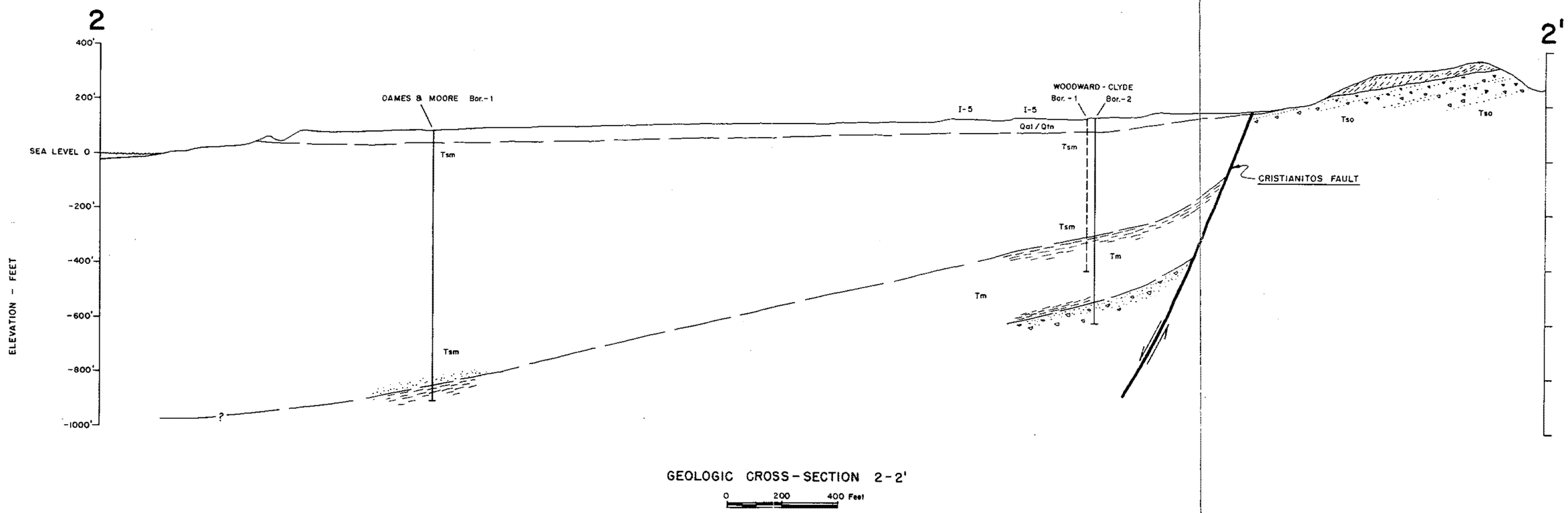


SAN ONOFRE
NUCLEAR GENERATING STATION

INDEX MAP
CROSS-SECTION 2-2'

PLATE 1



GEOLOGIC CROSS-SECTION 2-2'

GEOLOGIC CROSS-SECTION
SAN ONOFRE
NUCLEAR GENERATING STATION
UNITS 2 & 3
AUGUST, 1980
PLATE 2

2.5I-81

Woodward-Clyde Consultants

SUMMARY REPORT ON BASIC DATA FROM TWO ONSHORE AND SIX OFFSHORE GEOLOGIC BORINGS SONGS UNITS 2 AND 3 SAN ONOFRE, CALIFORNIA

Prepared for:

Southern California Edison Company
P. O. Box 800
Rosemead, California 91770

2.5I-82

Amended: April 2009 TL: E048000

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Woodward-Clyde Consultants

4 August 1980
Project No. 41299I

Southern California Edison
P.O. Box 800
Rosemead, California 91770

Attention: Mr. H. G. Hawkins

Gentlemen:

SUBJECT: SUMMARY REPORT ON BASIC DATA FROM TWO ONSHORE AND SIX OFFSHORE GEOLOGIC BORINGS SONGS UNITS 2 AND 3 SAN ONOFRE, CALIFORNIA

We have completed the drilling operations onshore (north of the Cristianitos fault) and the vibratory core borings to sample seafloor sediments offshore SONGS Units 2 and 3. These assignments were conducted under the direction of Messrs. H. G. Hawkins and J. L. McNey of Southern California Edison. This report provides a summary of field operations, drilling logs, and the results of age dating analyses. The data on onshore borings and offshore borings are presented in Sections 1 and 2, respectively. We hope that this summary report of basic data meets the project needs at this time.

If you have any questions, please call at your convenience.

Very truly yours,

John A. Barneich
Associate

George E. Brogan
Associate

JAB:GEB/ea
Attachments

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LETTER OF TRANSMITTAL

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TABLE 1 - Summary of Vibratory Cores

FIGURE 1 - Site Plan

APPENDIX 1-A - Logs of Borings

APPENDIX 1-B - Geophysical Logs

APPENDIX 1-C - Microfossil Age Dates

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APPENDIX 2-B - Age Dating Results

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SUMMARY REPORT ON BASIC DATA FROM TWO ONSHORE AND SIX OFFSHORE GEOLOGIC BORINGS SONGS UNITS 2 AND 3 SAN ONOFRE, CALIFORNIA

1.0 ONSHORE BORINGS

1.1 Introduction

Two onshore borings were drilled about 500 ft north of the Cristianitos fault at El Camino Real Road. The locations of borings are shown on Figure 1. This program was conducted under the direction of Southern California Edison. Geologic interpretations are being made by Southern California Edison. The purpose of this report is to present the logs of borings and to provide a brief description of the operations. Additional operational details are being kept on file by Woodward-Clyde Consultants.

1.2 Project Organization and Staffing

The program was conducted under the direction of Messrs. H. G. Hawkins and J. L. McNey of Southern California Edison. Messrs. J. A. Barneich and O. S. Ghuman from Woodward-Clyde Consultants coordinated and supervised the effort.

The drilling contractor for the onshore borings was Continental Drilling-U.S. from Madera, California. Mud engineering and supplies were obtained from Baroid and the geophysical logg. ng was done by Welenco from Bakersfield, California. The boring logs were kept by staff geologists.

1.3 Field Operations

The onshore borings were drilled using a Longyear 44 drill rig with HQ size drill pipe. The borings were advanced using

the rotary drilling method to depths at which coring was desired. Continuous wire line coring was then attempted using a 5 or 10 ft Longyear core barrel. Mud, as engineered by Baroid, was used as the circulating fluid. Core diameter was 3-1/2-inches.

Boring B-1

Boring B-1 was started on 22 May 1980. The boring was located about 500 ft north of the projected trace of the Cristianitos fault at its intersection with El Camino Real Road. After drilling into the San Mateo formation, a 4-inch diameter casing was installed to a depth of 58 ft. Attempts to obtain cores of the San Mateo sand were generally unsuccessful. It was decided to attempt further coring in the siltstone of the Monterey formation. Cores were obtained from 480 to 557 ft.

When the boring had advanced to 557 ft, it was decided to advance the casing to improve the drilling rate. During this operation about 100 ft of casing dropped into the hole. Repeated attempts to recover the casing were unsuccessful, and the boring was abandoned for later closure.

Boring B-2

Boring B-2 is located about 30 ft south of Boring B-1 along El Camino Real Road. It was started on 5 June 1980. The boring was advanced rapidly to about 400 ft using a roller tricone bit; and 4-inch-diameter casing was installed to 379 ft. Continuous wireline coring was done from about 483 to 750 ft. An attempt was made to remove the casing following completion of the hole, but only 15 ft of casing was retrieved.

Geophysical logs were run in Boring B-2 after drilling was completed. The runs included an electrical log giving the spontaneous potential and resistivity and a radioactivity log providing gamma ray and neutron logs.

After completion of the drilling and logging operations, the mud was weighted and the viscosity increased for closure. Both Borings B-1 and B-2 were then capped with a 3-sack cement-slurry plug. About 1 cu. yd. of slurry was placed in each boring. The logs of the borings are presented in Appendix 1-A and the geophysical logs in Appendix 1-B.

1.4 Summary of Boring Logs

The following is a summary of the stratigraphy obtained from the borings and a preliminary interpretation of the geophysical logs:

0 to 48 ft - Terrace Deposits - Sand. The colors range from pale brown (5YR5/2) to yellowish brown (10YR5/4) to red brown (10R5/4). The sand is fine to coarse grained, subrounded to well rounded, moderately to well sorted, with occasional lenses of clay and silt. Gravel and cobbles occur at the base of the terrace deposits. The deposit is poorly to moderately consolidated.

48 to 428 ft - San Mateo Formation - Sandstone. The colors of the San Mateo formation sandstone in Boring B-1 from a depth of 48 ft to about 200 ft are shades of yellowish brown, ranging from dusky yellow (5Y6/4) to pale yellowish brown (10YR6/2) to dark yellowish brown (10YR4/2). Between depths of 200 ft and 432 ft, the colors are shades of olive gray, mostly light olive gray (5YR5/2). The San Mateo formation in Boring B-2, consists of sandstone having a color of mostly light olive gray (5YR5/2). The texture of the San Mateo

formation consists of medium-to coarse-grained with some fine-grained sands. The sand grains are subangular to moderately well rounded. The formation is massive to thickly bedded, contains occasional pebbles and cobbles, and is slightly silty and micaceous locally. The approximate minerological composition is: Quartz 85-90%, feldspar 5-7%, and other minerals 5%. The basal contact with the Monterey formation occurs abruptly where drilling becomes harder.

428 to 669 ft - Monterey Formation - Siltstone. The formation is generally olive black (5Y2/1) in color, micaceous and contains highly fractured, slickensided and contorted areas. Bedding dip varies from horizontal to as much as 70 degrees and commonly includes thin 1/4-inch bluish gray beds. The siltstone is friable to well indurated with occasional sandy interbeds. Some sandy interbeds may contain volcanic ash.

Core samples between depths of 485 ft and 654 ft were examined for microfossils to estimate the age of the cores. The results of these analyses are presented in Appendix 1-C. Foram inifera samples collected from depths of 485 ft to 495 ft yield an age of Lower Mohnian (upper Miocene). Foram inifera samples collected from 654 ft are from the Luisian age (upper Miocene). The base of the Monterey formation from 658 ft to 669 ft contains abundant blue schist fragments and appears to be reworked San Onofre Breccia.

669 to 749.5 ft - San Onofre Breccia. This formation consists of bluish gray sandy breccia (5B5/1), with moderate to well cemented clay and silt matrix. The clasts range in size from sand particles to 4-inch cobbles; larger clasts mostly consist of chlorite and glaucophane schist and smaller clasts consist of quartzite and amphibole. The clasts are generally angular and are less weathered at increasing depths.

2.0 OFFSHORE BORINGS

2.1 Introduction

Vibratory cores were obtained at six selected locations offshore from San Onofre, California. The core locations are shown on Figure 1. This program was conducted under the direction of Southern California Edison. Geologic interpretations are being made by Southern California Edison on the basis of the results of the vibratory coring work. The purpose of this report is to provide a brief description of the field operations, to present the vibratory core logs and the results of age dating analyses. Additional operational details are being kept on file by Woodward-Clyde Consultants.

2.2 Project Organization and Staffing

The program was conducted under the direction of Messrs. H G. Hawkins and J. L. McNey of Southern California Edison. Messrs. J. A. Barneich, O. S. Ghuman and K. Bhushan from Woodward-Clyde Consultants coordinated and supervised the effort.

The vessel M/V Calcasieu belonging to Ocean Services, Inc. was mobilized in San Pedro for the vibratory coring work. Oceanmasters International Inc. provided the vessel Ocean Command as the crew boat. Woodward-Clyde Consultants operated the vibratory coring unit, logged the cores, and provided the navigation.

2.3 Field Operations

The sampling unit consists of a seafloor-supported quadruped frame with a vibrator - drill pipe assembly. The vibrator is operated by air supplied from a shipboard compressor and is mounted on a 40-ft long drill pipe. The drill pipe consists

of a standard 4-in. pipe with a cutting shoe and a sample retainer at the bottom. Samples are recovered in a removable 3-1/2-in. diameter plastic liner. The unit is also equipped for jetting in materials where full 40 ft penetration is not achieved in a single run. The water for jetting is supplied by a shipboard fire pump. Generally, a maximum of 40 ft of core can be recovered using this sampler. However, for the last run in boring 2-1 a 7-ft sampler extension was fitted and an attempt was made to penetrate as much as 47 ft.

Electronic navigation was provided using a Motorola Mini-Ranger III positioning system. This is a short range (20 nautical miles) line-of-sight system. The basic Mini-Ranger consists of a range console, receiver-transmitter, and omni-directional antenna installed on the boat. Two or three reference transponders are located at surveyed ground points. The measured ranges to the transponders are directly displayed in meters. The accuracy of the ranges is ± 3 meters at 20 nautical miles. The actual accuracy of the system is a function of the ranges and the angle of intersection of the two range lines. Conventional trilateration techniques are used to reduce the data. For the sampling program, two transponder stations were located along the coastline.

The boat was maneuvered using reference anchor locations that were calculated based on known anchor cable lengths. A three-point mooring system was used to maintain position. The vibratory coring assembly was carried horizontally suspended alongside the boat from two A-frames. After anchoring the boat on location, the bottom end of the corer was released so that the coring assembly was suspended vertically from the A-frame. The corer was lowered to the seafloor using a 20-ton capacity hoist. The air hoses connected to the vibrator were lowered along with the corer. After the

corer was seated on the seafloor, the air compressor was started to begin the coring. The penetration rate was recorded on a strip chart recorder. The air supply to the vibrator was stopped when no further penetration occurred. The core barrel was pulled out of the seafloor and the coring unit was retrieved. The bottom end of the coring unit was pulled with an air tugger to bring the unit into a horizontal position, and to remove the liner. The liner was cut at the point where the core stopped and the length of the core was measured and recorded. The recovered core (inside the liner) was then cut into convenient lengths (3 to 4 ft); logged by a geologist; capped and sealed at both ends; marked and stored. In all cases, full penetration to the desired depth could not be achieved on the first run. For each succeeding run, the liner, cutting shoe and sample retainer were reassembled, the coring unit was lowered to the seafloor, and the core barrel was advanced by jetting to a depth close to the bottom of the penetration achieved in the preceding run. After jetting to the desired depth, the vibratory coring operation was carried out as described previously. The number of runs at each site ranged between 2 and 5 and the maximum penetration achieved ranged between 25.5 and 44.1 ft.

A total of six sites were sampled, five on Line No. 1, and one on Line No. 2. Lines 1 and 2 refer to geophysical lines run by Fugro (Line 1) and Woodward-Clyde Consultants (Line 2). The location of the sites are shown on Figure 1. A summary of the vibratory coring operation is given on Table 1.

2.4 Summary of Cores

The six offshore borings, advanced utilizing the vibratory coring unit, penetrated to depths ranging from 25.5 to 44.1

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ft. In these intervals the materials encountered were mainly sands and silty sands with two of the cores (1-1 and 1-3) containing zones of clay and clayey silt.

The sandy sections of the cores were mainly fine grained, dark greenish gray in color, and contained variable amounts of silt. Cores 1-1, 1-2, 1-4 and 2-1 contained intervals of coarser grained sands ranging from fine to coarse grained and having a yellow gray to olive gray color.

The clayey intervals recovered in the cores were greenish black in color, and were found to be from 22.4 to 24.0 ft in Core 1-1, and from approximately 38.0 ft to the bottom (at 39.5 ft) in Core 1-3.

Fossils and other organic debris, such as wood and carbonaceous fragments, were also encountered in the cores. All of the cores contained random shells and shell fragments, and all of the cores, except 2-1, had small horizons that were rich enough in organic debris to collect samples for age dating. These organic rich horizons were mainly encountered from 0 to 25 ft, with the exception of Core 1-5 which had an abundance of organically rich material as deep as 38.5 ft.

Detailed logs of the cores are presented in Appendix 2-A. Age dates obtained from the analysis of organic materials and shells are presented in Appendix 2-B.

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TABLE 1

SUMMARY OF VIBRATORY CORING

CORE NO.	RUN NO.	PENETRATION BELOW SEAFLOOR, FEET FROM	TO	RECOVERY, FEET	APPROXIMATE WATER DEPTH, FEET
1-1	1	0	7.0	6.0	72
	2	5.0	25.5	20.1	72
1-2	1	0	22.4	22.4	100
	2	21.0	34.8	11.3	100
	3	32.0	39.5	6.5	100
1-3	1	0	22.4	24.4	125
	2	19.0	24.0	8.0	125
	3	25.0	30.8	9.2	125
	4	31.0	39.5	8.5	125
1-4	1	0	20.0	22.0	165
	2	16.0	23.0	9.0	165
	3	22.0	31.0	4.0	165
	4	31.0	39.5	10.0	165
1-5	1	0	21.5	21.5	200
	2	21.0	32.0	11.0	200
	3	31.0	35.8	5.0	200
	4	36.0	39.5	3.0	200
2-1	1	0	18.0	20.0	165
	2	19.5	30.0	11.0	165
	3	30.0	34.5	5.5	165
	4	35.0	39.3	4.5	165
	5	40.0	44.1	4.0	165

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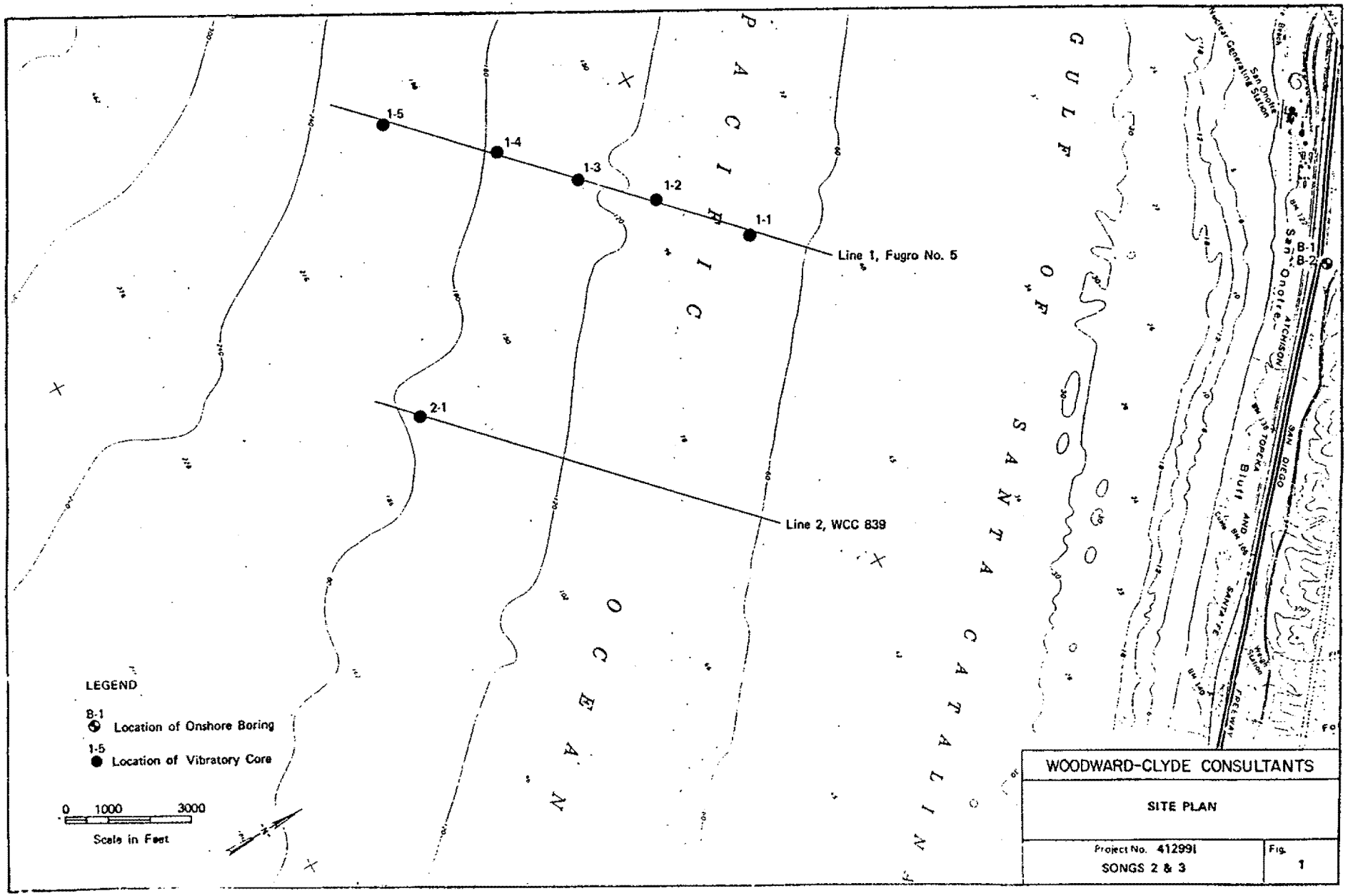
PACIFIC OCEAN
GULF OF SANTA CATALINA
1-5
1-4
1-3
1-2
1-1
Line 1, Fugro No. 5
2-1
Line 2, WCC 839
B-1
B-2
San Onofre
San Onofre Nuclear Generating Station
ATCHISON TOPEKA AND SANTA FE
SAN DIEGO FREEWAY
LEGEND
B-1 Location of Onshore Boring
1-5 Location of Vibratory Core
0 1000 3000
Scale in Feet
WOODWARD-CLYDE CONSULTANTS
SITE PLAN
Project No. 412991
SONGS 2 & 3
Fig. 1

APPENDIX 1-A

LOGS OF BORINGS

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Project No. 41299I Field Log of Boring No. B-1 Sheet 1 of 30

BORING LOCATION El Camino Real, East Side		ELEVATION AND DATUM El. 145 (approx.)	
DRILLING AGENCY Continental Drilling	DRILLER	DATE STARTED 5/22/80	DATE FINISHED 6/2/80
DRILLING EQUIPMENT Longyear 44		COMPLETION DEPTH 557'	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Standard		NO OF SAMPLES: DIST.	UNDIST. / CORE
DRILLING METHOD Rotary: HQ Drill pipe with wireline coring		WATER ELEV. FIRST	COMPL. / 24 HRS.
CORE BARREL Longyear HQ	LENGTH 5' and 10' / BIT	LOGGED BY: J. Glomb	CHECKED BY: O. S. Ghuman
N/A	N/A / N/A		

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
1	SAND, moderate yellowish brown, 10YR5/4, coarse grained, well sorted. SM	BAG SAMPLE NO. 1			
2					
3	becomes more dense.				
4					
5	some gravel to 1" diameter.				
6	cobbles and gravel sand becomes medium to coarse grained.				
7					
8	no gravel, color change to pale yellowish brown, 10YR6/2.				
9					
10	CLAY, very sandy, dark yellowish brown, 10YR4/2, medium grained, some gravel, 3-4" thick clay. CL				
11	SAND, reddish brown, 10R5/4, medium to coarse grained, with occasional gravel 1/4-1/2" in diameter, dense. SP	BAG SAMPLE NO. 2			
12					
13					
14	less dense.				
15					
16					

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Project No. 41299I Field Log of Boring No. B-1 Sheet 2 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
17	SAND, pale yellowish brown, 10YR6/2, medium to coarse grained with some fines. SM	BAG SAMPLE NO. 3			
18					
19					
20	becomes more dense yellowish brown, 10YR5/4, fine to medium grained, moderately well rounded, well sorted.				
21					
22					
23					
24					
25					
26	grades to grayish orange, 10YR7/4.				
27					
28					
29					
30		BAG SAMPLE NO. 4			
31					
32	less dense moderate yellowish brown, 10YR5/4, grades to medium grained.				
33					
34					
35					

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Project No. 41299I Field Log of Boring No. B-1 Sheet 3 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
36	SAND, moderate yellowish brown, 10YR5/4, fine and medium grained, well rounded, well sorted, bright yellow grains comprise about 5%. SP	BAG SAMPLE NO. 5			
37					
38					
39					
40					
41					
42					
43	gravel about 3" in diameter.				
44					
45	cobble layer				
46	medium grained, moderate yellowish brown, 10YR5/4, rounded quartz grains comprise 50-70%.				
47					
48	SANDSTONE (San Mateo Formation), moderate yellowish brown, 10YR5/4, coarse grained, well sorted, subangular, dark and colored grains 85% quartz. SP	BAG SAMPLE NO. 6			
49	cuttings are darker in color, probably due to ground-up cobbles, dark gray cobble chips, angular, comprise 30-40%.				
50					
51					
52					
53	grades to medium grain size.				
54					

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Project No. 41.2991 Field Log of Boring No. B-1 Sheet 4 of 5

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
55	SANDSTONE (San Mateo Formation), pale yellowish orange, 10YR8/6, medium to coarse grained, well sorted, quartz 85% sub-rounded, dark gray grains 10% subangular to sub-rounded, others 5% sub-angular. SP drilling slow, formation very dense.	BAG SAMPLE NO. 7			
56	grades to medium grained, some angular grains.				
57					
58					
59		BAG SAMPLE NO. 8	1	No Recovery	
60					
61					
62					
63					
64					
65					
66					
67	very uniform coring.	BAG SAMPLE NO. 9	2	No Recovery	
68					
69					
70					
71					
72					
73					

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Project No. 41299I Field Log of Boring No. B-1 Sheet 5 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
74	SANDSTONE, pale yellowish brown, 10YR6/12, medium grained, very dense, well sorted, quartz 85% sub-rounded to rounded, dark gray grains 10% subangular to sub-rounded, others 5%. SP				
75		BAG SAMPLE NO. 10	3	No Recovery	
76					
77		BAG SAMPLE NO. 11	4	No Recovery	
78					
79		BAG SAMPLE NO. 12	5	No Recovery	
80					
81					
82					
83					
84					
85		BAG SAMPLE NO. 13	6	No Recovery	
86					
87					
88					
89					
90			7	No Recovery	
91					
92					

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Project No. 41299I Field Log of Boring No. B-1 Sheet 6 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
93	SANDSTONE, pale yellowish brown, 10YR6/2, medium to coarse grained, well sorted, quartz 85-90% sub-rounded, dark minerals 10% subangular. SP	BAG SAMPLE NO. 14	7	No Recovery	
94					
95					
96		BAG SAMPLE NO. 15	8	No Recovery	
97					
98					
99					
100					
101		BAG SAMPLE NO. 16	9	No Recovery	
102					
103					
104					
105					
106					
107					
108	grading to coarse grained.	BAG SAMPLE NO. 17	10		
109					
110					
111					

Project No. 412991 Field Log of Boring No. B-1 Sheet 7 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
112	SANDSTONE, pale yellowish brown, 10YR6/2, medium grained, well sorted, dense, quartz 85% sub-rounded to rounded, dark gray grains 10% subangular to sub-rounded, others 5% sub-rounded to subangular. Some silt present. SP		10	No Recovery	
113					
114		BAG SAMPLE NO. 18			
115			11	No Recovery	
116					
117					
118					
119	SANDSTONE, grayish orange, 10YR7/4, coarse to medium grained, well sorted, massive crumbly, occasional 1/4-1/2" pebbles, dense, 85% sub-rounded quartz, 15% sub-rounded others. SP				
120			12	27% - 41%	
121					
122					
123					
124		BAG SAMPLE NO. 19			
125					
126			13	2% - 4%	
127					
128					
129					
130			14		

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Project No. 412991 Field Log of Boring No. B-1 Sheet 8 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
131		BAG SAMPLE NO. 20	14	No Recovery	
132					
133					
134	SANDSTONE, silty, moderate yellowish brown, 10YR5/4, medium to fine grained, predominately sub-rounded quartz grains. SW				
135					
136		BAG SAMPLE NO. 21	15	No Recovery	
137					
138					
139	SANDSTONE, silty, dusky yellow, 5Y6/4, fine grained, massive, subangular (gritty feel). SW				
140					
141					
142			16	No Recovery	
143					
144					
145					
146					
147	dusky yellow, 5Y6/4, grades from fine to medium grained, slightly silty, massive, subangular, predominately quartz. SP	BAG SAMPLE NO. 22	17	No Recovery	
148					
149					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
150	gravel layer 2" thick, 1/2-1" diameter, rounded.	BAG SAMPLE NO. 23	18	8" - 10%	
151	SANDSTONE, dark yellowish brown, 10YR4/2, coarse grained, gravelly, subangular to sub-rounded quartz (60%) and feldspar (25%).				
152					
153					
154					
155					
156		BAG SAMPLE NO. 24	19		
157					
158					
159					
160			20		
161					
162					
163					
164					
165					
166					
167					
168					

Project No. 41299I Field Log of Boring No. B-1 Sheet 10 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
169	SANDSTONE, dusky yellow, 5Y6/4, medium to fine grained, subangular to sub-rounded quartz (65%) with occasional rounded gravel (1/2"-2" diameter). SP		20	1/2' — 4%	
170					
171	CLAY, sandy layer, light olive brown, 5Y5/6, with rounded pebbles.				
172		BAG SAMPLE NO. 25	21	No Recovery	
173					
174					
175					
176					
177					
178					
179					
180					
181					
182					
183			22		
184					
185					
186					
187					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
188	SANDSTONE (San Mateo Formation), dusky yellow, 5Y6/4, medium grained, quartz 95% sub-rounded, others 5% sub-rounded, occasional gravel. SP	BAG SAMPLE NO. 26	22	NO RECOVERY	
189					
190					
191					
192					
193					
194		BAG SAMPLE NO. 27	23		
195					
196					
197					
198	gravel 3/4"-1" diameter.				
199					
200					
201					
202					
203					
204			24		
205					
206					

Project No. 41299I Field Log of Boring No. B-1 Sheet 1 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
207	SANDSTONE, light olive gray, 5Y5/2, fine grained, slightly silty, gritty, with occassional (0-5%) very coarse sand and pebbles, massive, friable. SP	BAG SAMPLE NO. 28	24	No Recovery	
208					
209					
210					
211					
212					
213					
214		BAG SAMPLE NO. 29	25	1ft	
215					
216		BAG SAMPLE NO. 30	26	No Recovery	
217	Thin hard layer.				
218					
219					
220					
221					
222					
223					
224					
225					

Project No. 41299I Field Log of Boring No. B-1 Sheet 13 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
226	hard layer SANDSTONE, medium light gray, N6, medium to fine grained, silty, very dense, sub-rounded quartz (85%) with small (1 mm) blebs of silt and 2-5% biotite flakes. SW	BAG SAMPLE NO. 31	27	18	
227					
228					
229					
230					
231					
232					
233					
234		BAG SAMPLE NO. 32	28		
235	alternating 6" hard layers with 12-18" softer layers SANDSTONE, dark gray, N3, fine to coarse grained with sandy SILT (40%). SW				
236					
237					
238		BAG SAMPLE NO. 33	29		
239					
240	CLAY, sandy, dark gray, N3, fine to medium grained (scraped from core barrel tip). CL				
241					
242					
243					
244					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
245					
246					
247					
248	SANDSTONE, light olive gray, 5Y5/2, silty, with trace of clay, fine-grained, some iron oxide stains. SW	BAG SAMPLE NO. 34	30	No Recovery	
249					
250					
251					
252					
253					
254	SANDSTONE (San Mateo Formation), yellowish gray, 5Y7/2, medium grained, sub-rounded to subangular, quartz 95% other dark minerals 5%, sub-rounded. SP	BAG SAMPLE NO. 35	31	No Recovery	
255					
256					
257					
258					
259					
260					
261					
262					
263					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
264					
265	SANDSTONE, yellowish gray, 5Y7/2, medium grained, sub-angular to sub-rounded. Quartz 95%, other dark minerals 5% subangular. SP				
266					
267		BAG SAMPLE NO. 36			
268			32	No Recovery	
269					
270					
271					
272					
273	SANDSTONE (San Mateo Formation), dusky yellow, 5Y6/4, very dense, poorly sorted, with gravel to 1/4", quartz 85% subrounded, feldspars 10% sub-rounded, other 5% angular to sub-rounded, trace of clay. SW				
274		37			
275					
276					
277		BAG SAMPLE NO. 38			
278			33		
279					
280					
281					
282					

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Project No. 41293 Field Log of Boring No. B-1 Sheet 16 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
283	SANDSTONE (San Mateo Formation), yellowish gray, 5Y7/2, medium to fine grained 90% quartz sub-rounded. SP	BAG SAMPLE NO. 39	33		
284					
285					
286					
287	SANDSTONE, medium light gray , N61/2, fine grained, gravel 1/4" sub-rounded, massive, no bedding 90% quartz sub-rounded, feldspars 5% sub-rounded, dark minerals 5% subangular to sub-rounded. SW	BAG SAMPLE NO. 40	34	2' 8 1/2"	
288					
289					
290					
291					
292					
293					
294					
295					
296					
297					
298		BAG SAMPLE NO. 41	35	No Recovery	
299					
300					
301					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
302	SANDSTONE (San Mateo Formation), medium light gray, N61/2, fine to medium grained, some 1/4" gravel, gravel sub-rounded, massive no bedding 90% quartz sub-rounded, feldspars 5% sub-rounded, dark minerals 5% subangular to sub-rounded. SP	BAG SAMPLE NO. 42	35	No Recovery	
303					
304					
305					
306					
307					
308		BAG SAMPLE NO. 43	36	38	
309					
310					
311					
312					
313					
314		BAG SAMPLE NO. 44	37		
315					
316					
317					
318					
319					
320					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
321	SANDSTONE (San Mateo Formation), light olive gray 5Y5/2, fine to medium grained, some 1/4" diameter gravel, sub-rounded, massive no bedding quartz 85% sub-rounded, feldspars 10% sub-rounded, others 5% sub-rounded. SP	BAG SAMPLE NO. 45	37	No Recovery	
322					
323					
324					
325					
326					
327					
328					
329					
330					
331		BAG SAMPLE NO. 46			
332					
333					
334					
335					
336					
337					
338	SANDSTONE, light olive gray, 5Y5/2, fine to medium grained, predominately subangular to sub-rounded quartz, massive slightly silty. SP		38		
339					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
340	SANDSTONE (San Mateo Formation), light olive gray, 5Y5/2, medium to carse grained, sub-rounded, quartz 80%, feldspars 10%, dark minerals 10%. SW	BAG SAMPLE NO. 47	38		
341					
342					
343					
344					
345					
346					
347					
348		BAG SAMPLE NO. 48	39		
349					
350					
351					
352					
353					
354					
355					
356					
357					
358					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
359	SANDSTONE, light olive gray, 5Y5/2, medium grained, sub-rounded, quartz 80%, feldspars 10% dark minerals 10%. SF	BAG SMPLE NO. 49	40		
360					
361					
362					
363					
364	hard layer encountered only a few inches thick.				
365					
366					
367					
368		BAG SMPLE NO. 50	41		
369					
370					
371					
372					
373					
374					
375					
376					
377					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
378	SANDSTONE, light olive gray, 5Y5/2, medium to coarse grained, sub-rounded, quartz (70%), feldspars (15%) and dark minerals (15%), massive. SP	BAG SAMPLE NO. 51	42		
379					
380					
381					
382					
383					
384					
385					
386					
387					
388		BAG SAMPLE NO. 52	43		
389					
390					
391					
392	hard layer				
393					
394	hard layer dark minerals make up noticeably greater percentage (20%).				
395					
396					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
397			43		
398					
399					
400					
401					
402			11		
403					
404					
405					
406					
407					
408					
409	SANDSTONE, light olive gray, 5Y5/2, sub-rounded to subangular, medium grained, quartz (80%), feldspar (10%), and dark grains (10%), occasional coarse grains to 1/4". SP				
410					
411	hard layer				
412			45		
413					
414					
415					

BAG SAMPLE NO. 53

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
416			45		
417					
418					
419	SANDSTONE, medium gray, N5, medium grained, quartz 75% sub-rounded, feldspar 10% sub-rounded, dark minerals 15% sub-rounded to subangular. SP	BAG SAMPLE NO. 54	46		
420					
421					
422					
423					
424					
425					
426					
427					
428					
429		BAG SAMPLE NO. 55	47		
430					
431					
432					
433					
434					

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
435	SANDSTONE, medium gray, N5, medium grained, quartz 75% sub-rounded, feldspars 10%, dark minerals 15-20% sub-angular to sub-rounded.	BAG SAMPLE NO. 56	47		
436					
437					
438					
439		BAG SAMPLE NO. 57	48		
440					
441					
442					
443					
444	Harder drilling, color of drilling mud changed to olive gray.				
445	SILTSTONE, dark gray, N3, with fine grained micaceous sand. ML				
446					
447					
448			49		
449					
450					
451					
452	easier drilling.				
453					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
454	SILTSTONE, olive gray, 5Y4/1, parallel horizontally bedded 1/2 thick, with very thin lenses of fine grained sand, micaceous. No visible joints or fractures, little or no weathering, low permeability. ML		50		
455					
456					
457					
458					
459			51	100%	
460	Light weathering, and lightly jointed generally at 50°.				
461					
462					
463		BAG SAMPLE NO. 58	52	No Recovery	
464					
465					
466					
467		BAG SAMPLE NO. 59	53	No Recovery	
468					
469					
470					
471					
472	Sample yields age of Lower Mohnian (Upper Miocene)				

Amended: April 2009 TL: E048000

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
473		BAG SAMPLE NO. 60	54	No Recovery	
474					
475					
476					
477					
478	SILTSTONE, grayish olive, 10Y4/2, parallel horizontally bedded 1 1/2" thick with very thin lenses of fine grained sand, micaceous. Some 3/4-1" gravel sub-rounded, slickensides, moderately weathered, and fractured, no visible joints, low permeability. Forams and fish scales.		55	60%	
479					
480					
481					
482					
483					
484			56	33%	
485	Sample yields age of Lower Mohnian (Upper Miocene). SANDSTONE, olive gray, 5Y4/1, cross bedded, fine grained well cemented, very well indurated. Jointed at 30° and 85°, moderately fractured. SP				
486	SILTSTONE, olive black, 5Y2/1, parallel horizontally bedded 1/2" to 1 1/2" thick, micaceous with mineral spots possibly gypsum. ML		57	60%	
487					
488					
489	highly weathered, highly fractured.				
490					
491					

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Project No. 41299I Field Log of Boring No. B-1 Sheet 27 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
492	SILTSTONE, olive black, 5Y2/1, parallel bedding ranging from horizontal to 35°, 1/2" thick with very thin interbedding of fine grained sand, has bluish gray 1/4" thick beds. ML		58	100%	
493					
494	Samples taken at 493.5' and 495' yield age of Lower Mohnian (Upper Miocene). Highly weathered, moderately fractured, joints vertical to 45°				
495	Well indurated, no fracturing, joints at 30°, 1/4" bluish gray beds are irregularly laid.				
496					
497	SILTSTONE, olive black, 5Y2/1, fissile to moderately fractured, fractures generally parallel to bedding but also highly angled oblique to bedding, siltstone poorly indurated, irregularly bedded with medium bluish gray micaceous clay, bedding horizontal to 30°, at 500' beds highly contorted suggesting slumping, clay beds 1/16" to 1/2" thick. Generally in uniform lenticular shape but minor oblate pods also. ML		59	100%	
498					
499					
500					
501					
502					
503			60	No Recovery	
504					
505					
506					
507	SILTSTONE, olive black, 5Y2/1, moderately fractured, fractures generally parallel to bedding, becoming more indurated brittle with lenticular white sand size grains of a micaceous material, also inclusions to 1/2" diameter sub-rounded, tan, fine grained sandstone, interbedded with irregular spaced lenses of bluish gray micaceous siltstone, bedding dips 15-30°, lenses to 1/4" thick. ML		61	100%	
508					
509					
510					

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Project No. 612991 Field Log of Boring No. B-1 Sheet 2 of

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
511			61	10.8	
512	SILTSTONE, olive black, 5Y2/1, with irregular spaced lenses and irregular shaped pods of bluish gray micaceous siltstone. ML				
513			62	7.2	
514					
515			63	No Recovery	
516					
517	SILTSTONE, olive black, 5Y2/1 with irregular spaced beds of bluish gray micaceous siltstone, bedding 10-30°, lenses 1/8"-1/4" thick, at 518.5' many lenses offset 1/8" along high angle fractures (50-65°). ML				
518			64	9.8	
519					
520	SILTSTONE, interbedded olive black, 5Y2/1, and bluish gray micaceous siltstone, highly contorted bedding with minor offset of beds, compaction or slumping of soft sediments causing pinching out and irregular structures within bedding. ML				
521			65	25.8	
522					
523					
524	SILTSTONE, fragments, olive black, 5Y2/1, disoriented siltstone fragments within matrix of bluish gray micaceous silty clay, one siltstone fragment contains imprint of fossil of unknown affinity. ML				
525			66	17.8	
526					
527					
528	SILTSTONE, olive black, 5Y1/2, very brittle to moderately indurated, disoriented, fractures generally parallel to bedding, dips horizontal to 20°, siltstone more indurated below 529', irregularly spaced bluish gray lenses 1/16-1/8" thick. ML		67	7.0	
529					

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Project No. 412991 Field Log of Boring No. B-1 Sheet 29 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
530			67	70%	
531					
532					
533	SILTSTONE, brownish black, 5YR2/1, bedding generally parallel ranging from horizontal to 40°, fracture parallel to bedding planes, bedding 1/2-2" thick, some vertical joints visible, bluish gray beds 1/8-1/4" thick, highly fractured and weathered at 532-534', more indurated below 534'. ML		68	100%	
534					
535					
536					
537	Highly fractured zone, siltstone crumbles easily.				
538			69	100%	
539	Siltstone more indurated.				
540					
541					
542					
543	less indurated fractured, weathered.		70	27%	
544					
545					
546					
547					
548	Highly fractured				

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Project No. 412991 Field Log of Boring No. B-1 Sheet 30 of 30

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
549 550	SILTSTONE, brownish black, 5YR2/1, bedding ranging from horizontal to 40° dip, bedding thickness from 1" to 3", fracturing generally in direction of bedding, moderately indurated, crumbles easily, some bluish gray beds present generally 1/8 to 1/4" thick. ML		71	100%	
551 552 553 554 555	SILTSTONE, brownish black, 5YR2/1, bedding generally horizontal to 35° dip, highly fractured below 551' with fractures ranging from horizontal to near vertical. ML. parallel bedding, highly weathered.		72	18%	
556 557				50%	
558 559 560 561 562 563 564 565 566 567	unable to reenter boring after loss of casing. Bottom of boring at 557'.				

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Project No. 41299I Field Log of Boring No. B-2 Sheet 1 of 40

BORING LOCATION El Camino Real Sta. 67 + 55 PMF Survey Work		ELEVATION AND DATUM El. 145 (approx.)	
DRILLING AGENCY Continental Drilling	DRILLER Mike Kuchler	DATE STARTED 6/05/80	DATE FINISHED 6/18/80
DRILLING EQUIPMENT Longyear 44		COMPLETION DEPTH 749.5	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Standard		NO OF SAMPLES: DIST.	UNDIST. / CORE
DRILLING METHOD Rotary: HQ Drill pipe with wireline coring		WATER ELEV. FIRST	COMPL. / 24 HRS.
CORE BARREL Longyear HQ	LENGTH 5' and 10' / BIT Diamond	LOGGED BY: Hector Reyes	CHECKED BY: O. S. Ghuman

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
1	SAND, silty, pale brown, 5YR5/2, medium to coarse grained, angular to sub-rounded, sand is mainly quartz, some broken rock fragments. SM	BAG SAMPLE NO. 1			
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13	SAND, silty to clayey, pale brown, 5YR5/2, fine to coarse grained, angular to sub-rounded, poorly sorted, silt and clay mixed with some gravel and broken rock fragments. SM-SC				
14					
15					
16					

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Project No. 412991 Field Log of Boring No. B-2 Sheet 4 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
17	SAND, light olive gray, 5YR5/2, medium grained, sub-angular to sub-rounded, well sorted, mostly quartz with some rock fragments. SP				
18					
19		BAG SAMPLE NO. 2			
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32		BAG SAMPLE NO. 3			
33					
34					
35					

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Project No. 41299I Field Log of Boring No. B-2 Sheet 3 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, fine to medium grained, sub-rounded, well sorted, mostly quartz with some rock fragments, poorly cemented, formation denser than above. SP	BAG SAMPLE NO. 4			
48					
49					
50					
51					
52	SAND, medium grained, gradational change. SW				
53					
54					

Project No. 412991 Field Log of Boring No. B-2 Sheet 4 of 4

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
55	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium grained, sub-rounded, well sorted, mostly quartz with some rounded rock fragments. SW	BAG SAMPLE NO. 5			
56					
57					
58					
59					
60					
61					
62					
63					
64					
65					
66					
67					
68					
69		BAG SAMPLE NO. 6			
70					
71					
72					
73					

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Project No. 912391 Field Log of Boring No. B-2 Sheet 5 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
74					
75					
76					
77					
78	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, coarse grained, sub-rounded to subangular, well sorted, poorly cemented, mostly quartz with some rock fragments. SW	BAG SAMPLE NO. 7			
79					
80					
81					
82					
83					
84					
85	grading to coarse grained.				
86					
87					
88					
89		BAG SAMPLE NO. 8			
90					
91					
92					

Project No. 412991 Field Log of Boring No. B-2 Sheet 6 of 10

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
93	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium grained, sub-rounded, quartz 90%, feldspar 5%, other 5%. SW				
94					
95					
96					
97	grades to medium grained.				
98					
99					
100					
101					
102					
103					
104					
105					
106					
107	grades fine to medium grained.				
108					
109					
110					
111					

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Project No. 41299I Field Log of Boring No. B-2 Sheet 7 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
112	SANDSTONE, (San Mateo Formation), light olive gray 5YR5/2, medium grained, sub-rounded. SW	BAG SAMPLE NO. 11			
113	grades to coarse grained.				
114					
115					
116					
117					
118					
119					
120					
121	START RECORDING RUNS.	BAG SAMPLE NO. 12	12		
122					
123					
124					
125					
126					
127					
128					
129					
130					

Project No. 412991 Field Log of Boring No. B-2 Sheet 8 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
131	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium grained, sub-rounded, quartz 90%, feldspar 5%, others 5%, dense formation. SP	BAG SAMPLE NO. 13	13		
132					
133					
134					
135					
136					
137					
138					
139					
140					
141					
142		BAG SAMPLE NO. 14	14		
143					
144					
145					
146					
147					
148					
149					

Project No. 412991 Field Log of Boring No. B-2 Sheet 9 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
150			14		
151	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium grained, sub-rounded, quartz 90%, feldspar 7%, others 3%. SP				
152					
153					
154					
156		BAG SAMPLE NO. 15			
156			15		
157					
158					
159					
160					
161	grades to fine grained.				
162					
163					
164		BAG SAMPLE NO. 16			
165			16		
166					
167					
168					

Project No. 412991 Field Log of Boring No. B-2 Sheet 10 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
169			16		
170	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium grained, sub-rounded. SP				
171					
172		BAG SAMPLE NO. 17	17		
173					
174					
175					
176					
177					
178					
179					
180					
181					
182		BAG SAMPLE NO. 18	18		
183					
184					
185					
186					
187					

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Project No. 41299T Field Log of Boring No. B-2 Sheet 11 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	RQD
188	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium to fine grained, sub-rounded, well sorted, dense, quartz 90%, feldspar 7%, others 3%. SP				
189					
190					
191					
192		BAG SAMPLE NO. 19	19		
193					
194					
195					
196					
197					
198					
199					
200					
201					
202		BAG SAMPLE NO. 20	20		
203					
204					
205					
206					

Project No. 412991 Field Log of Boring No. B-2 Sheet 12 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
207					
208	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium to fine grained, sub-rounded, well sorted, quartz 90%, feldspar 7%, others 3%. SP		20		
209					
210					
211					
212					
213					
214					
215		BAG SAMPLE NO. 21			
216			21		
217					
218					
219					
220					
221					
222		BAG SAMPLE NO. 22			
223			22		
224					
225					

Project No. 412991 Field Log of Boring No. B-2 Sheet 13 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
226					
227	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, medium to fine grained, sub-rounded, well sorted, quartz 90%, feldspar 5%, others 5%. SP				
228			22		
229					
230					
231					
232					
233					
234					
235		BAG SAMPLE NO. 23			
236			23		
237					
238					
239					
240					
241					
242					
243			24		
244					

Project No. 41299I Field Log of Boring No. B-2 Sheet 14 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
245		BAG SAMPLE NO. 24	24		
246	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, mostly fine grained with some medium grained, subangular to sub-rounded, well sorted, quartz 90%, feldspar 5%, others 5%. SP				
247					
248					
249					
250					
251					
252		BAG SAMPLE NO. 25	25		
253					
254					
255					
256					
257					
258					
259					
260					
261					
262			26		
263					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
264	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, mostly fine grained, subangular to sub-rounded, well sorted, quartz 90%, feldspar 5%, others 5%. SP	BAG SAMPLE NO. 26	26		
265					
266					
267					
268					
269					
270					
271					
272		BAG SAMPLE NO. 27	27		
273					
274					
275					
276					
277					
278					
279					
280					
281					
282			28		

Project No. 412991 Field Log of Boring No. B-2 Sheet 16 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
283	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, fine to medium grained, sub-rounded to sub-angular, well sorted, quartz 90%, feldspar 5%, others 5%. SP	BAG SAMPLE NO. 28	28		
284					
285					
286					
287					
288					
289					
290					
291	medium grained with fewer fines.	BAG SAMPLE NO. 29	29		
292					
293					
294					
295					
296					
297					
298					
299					
300					
301					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
302	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, fine to medium grained, sub-rounded to sub-angular, well sorted, quartz 90%, feldspar 5%, others 5%. SP	BAG SAMPLE NO. 30	30		
303					
304					
305					
306					
307					
308					
309					
310					
311					
312		BAG SAMPLE NO. 31	31		
313					
314					
315					
316					
317					
318					
319					
320					

Project No. 41299I Field Log of Boring No. B-2 Sheet 18 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
321			31		
322	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, fine to medium grained, subangular to subrounded, well sorted, quartz 90%, feldspar 5%, others 5. SP	BAG SAMPLE NO. 32	32		
323					
324					
325					
326					
327					
328					
329					
330					
331					
332		BAG SAMPLE NO. 33	33		
333					
334					
335					
336					
337					
338					
339					

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Project No. 412991 Field Log of Boring No. B-2 Sheet 19 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
340	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, fine to medium grained, subangular to subrounded, well sorted, quartz 90%, feldspar 5%, others 5%. SP		33		
341					
342					
343					
344					
345		BAG SAMPLE NO. 34			
346			34		
347					
348					
349					
350					
351					
352					
353					
354		BAG SAMPLE NO. 35			
355			35		
356					
357					
358					

Project No. 41299I Field Log of Boring No. B-2 Sheet 20 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
359	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, fine to medium grained, sub-rounded to sub-angular, well sorted, quartz 90%, feldspar 5%, others 5%. SP		35		
360					
361					
362		BAG SAMPLE NO. 36	36		
363					
364					
365					
366					
367					
368					
369					
370					
371					
372		BAG SAMPLE NO. 37	37		
373					
374					
375					
376					
377					

Project No. 41299I Field Log of Boring No. B-2 Sheet 21 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
378	SANDSTONE (San Mateo Formation), light olive gray, 5YR5/2, coarse to medium grained, sub-rounded, well sorted, quartz 90%, feldspar 5%, others 5%, trace of 1/4" gravel. SP		37		
379					
380		BAG SAMPLE NO. 38			
381					
382					
383					
384					
385			38		
386					
387					
388					
389	SANDSTONE, light olive gray, 5YR5/2, Coarse grained, sub-rounded, with some 1/4" diameter gravel. SW				
390					
391					
392		BAG SAMPLE NO. 39			
393					
394			39		
395					
396					

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Project No. 412991 Field Log of Boring No. B-2 Sheet 22 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
397	SANDSTONE, (San Mateo Formation), light olive gray, 5YR5/2, coarse to medium grained, well sorted, subrounded, quartz 90%, feldspars 5%, others 5%, trace 1/4" gravel. SP		39		
398					
399					
400					
401					
402		BAG SAMPLE NO. 40	40		
403					
404	Color change to medium light gray, N5, medium grained.				
405					
406					
407					
408					
409					
410					
411					
412			41		
413					
414					
415					

Project No. 41299I Field Log of Boring No. B-2 Sheet 23 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
416					
417	SANDSTONE (San Mateo Formation), light olive gray, 5YR4/1, medium grained, sub-rounded, well sorted, quartz 85%, feldspar 5%, others 10%. SP		41		
418					
419					
420					
421					
422					
423					
424					
425		BAG SAMPLE NO. 42			
426			42		
427					
428					
429					
430					
431	SILTSTONE (Monterey Formation), medium dark gray, N4, highly micaceous. ML				
432					
433			43		
434					

Project No. 412991 Field Log of Boring No. B-2 Sheet 24 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
435	SILTSTONE (Monterey Formation), medium dark gray, N4, very micaceous. ML				
436					
437			43		
438					
439					
440					
441					
442					
443					
444					
445					
446			44		
447					
448					
449					
450					
451					
452			45		
453					

Amended: April 2009 TL: E048000

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
454	SILTSTONE (Monterey Formation), medium dark gray, N4, abundant mica, some fine sand, possible chert lense or concretion from 456' to 457'. ML				
445					
456					
457			45		
458					
459					
460	SANDSTONE, olive gray, 5YR3/2, fine to coarse grained (mostly medium grained), with a small amount of rounded pebbles and broken gravel, sand is subangular to sub-rounded, poorly to moderately sorted (high percentage of silt), quartz 80%, feldspar 5%, others 15%. Note: Some of the above material may be the solids the driller is trying to wash out from the inside of the rod.				
461					
462					
463					
464					
465					
466			46		
467					
468	sand becomes darker in color and fine grained below 468'. Also silt content increases.				
469					
470					
471	SILTSTONE, dark olive gray, 5YR2/1, very micaceous, slightly sandy.				
472			47		

Amended: April 2009 TL: E048000

Project No. 412991 Field Log of Boring No. B-2 Sheet 26 of 4[illegible]

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
473	SILTSTONE (Monterey Formation), dark olive gray, 5YR2/1, high mica content, some very fine sand. ML	BAG SAMPLE NO. 43	47		
474					
475					
476					
477					
478					
479					
480					
481					
482	Began coring at 482.8' (slight caving in hole at start of run #49).		48		
483					
484			49		
485					
486	SANDSTONE, light olive gray, 5YR6/1, fine grained, very well indurated, bedding at 25°, 1/16" to 1/8" thick.				
487	SILTSTONE, olive black, 5YR2/1, parallel bedding 15°, 1" to 4" thick, interbedded with very fine grained sand, highly micaceous, little to no weathering, highly fractured zone, slickensides in some fragments. ML				
488					
489			50	75%	
490	Unfractured siltstone.				
491					

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Project No. 41299I Field Log of Boring No. B-2 Sheet 27 of 4

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
492	SILTSTONE (Monterey Formation), olive black, 5YR2/1, parallel bedding dipping 15° to 23°, 1" to 2" thick with many interbeds of bluish gray micaceous siltstone 1/16" to 1/4" thick parallel to bedding, many very small white, lenticular, sand sized grains of micaceous material (?) within the dark siltstone, moderately fissile with most joints parallel to bedding, well indurated, little or no weathering. ML		50	75%	
493					
494					
495			51	100%	
496					
497					
498					
499					
500					
501	SILTSTONE, olive black, 5YR2/1, with bluish gray interbeds, occasional dark olive green fine sand lenses, dips range from vertical to horizontal, with fractures parallel to bedding, most of the cored section is highly brecciated with contorted bedding, minor offsets of beds and irregular compaction or slumping structures, also with some slickenside surfaces indicating movement, bedding thickness ranges from less than 1/16" to 4", material is highly micaceous, weathering ranges from very little to moderate. ML		52	100%	
502					
503					
504					
505					
506					
507					
508					
509					
510					

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
511	SILTSTONE (Monterey Formation), olive black, 5YR2/1, contains 1/8" to 1/16" thick bluish gray contorted interbeds (to 516'), horizontal bedding 1/4" thick, fractures parallel to bedding, slickensided surfaces, some thin lenses of very fine grained sand, very highly fractured (to 512'), angular unconformity at 516', bedding dips 70°, still displays slickensides along bedding planes and fractures, moderate weathering. ML		53	82%	
512					
513					
514					
515					
516					
517					
518					
519					
520	SILTSTONE, olive black, 5YR2/1, bedding 1/4" to 2" thick with thin 1/4" to 1/16" bluish gray interbeds and discontinuous lenses of claystone, dips range from 20° to 35° with an apparent angular unconformity at 522', fractures generally parallel bedding, very highly fractured at 523' with slickenside surfaces common throughout cored section, moderate weathering. ML		54	80%	
521					
522					
523					
524					
525			55	42%	
526	The upper 16" of the core in Run #55 appears to be material that has fallen into the bottom of the hole and was then shoved into the core barrel. No structure to it.				
527	32" of Run #56 was extracted from the core barrel, however the upper 16" of this core appeared to be material that had fallen into the hole while the rods were pulled. The actual cored material is as above with angular unconformities in the core, with dips of approximately 20°. ML		56	100%	
528					
529			57	100%	

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
	Part of core very jumbled, lower part is intensely fractured siltstone with slickensides and a small concretion @ 529', with a poorly preserved clam shell cast. ML	?	57	100	
530					
531	SILTSTONE (Monterey Formation), olive black, 5YR2/1, with some bluish gray interbeds of clayey material 1/16" to 1/8" thick, upper 10" of core is rubble from caving of the hole (not calculated in % recovery), the majority of the core is very jumbled with randomly oriented siltstone particles in a clayey matrix, some bedding is contorted and some is parallel with dips 30° to 45° and fractures along bedding planes, many slickenside surfaces and intensely fractured zones. ML		58	71%	
532					
533					
534					
535			59	No recovery	
536					
537	SILTSTONE, olive black, 5YR2/1, upper 20" of core is rubble that has fallen into hole, jumbled and contorted to 537.8', last 2 to 3" is a very fine sandy layer. ML		60	51%	
538					
539	SILTSTONE, olive black, 5YR2/1, interbedded with bluish gray siltstone ranging from 1/16 to 1" thick, bedding generally diping 30° to 45°, displacement of 1/2" in beds displayed across fractures normal to bedding planes, slickensides exhibited along bedding planes, moderately fractured and weathered. ML		61	75%	
540					
541					
542					
543	Upper 2' of core very jumbled with broken siltstone particles in a bluish gray clay matrix, some minor offsets beds and a few slickensides. ML		62	100%	
544					
545					
546					
547	SILTSTONE, olive black, 5YR2/3, with very few bluish gray clayey interbeds (1/16" to 1/4"), bedding is parallel and dips at 20° to 25°, high percentage of fine sand in the lower 1 1/2' of the cored section, most fractures are along bedding planes although some range to >70°, a few		63	80%	
548					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
	slickensides found along fractured surfaces, weathering and fracturing are moderate. ML		[illegible]	[illegible]	
549					
550					
551	SILTSTONE (Monterey Formation), olive black, 5YR2/1 poorly defined bedding planes distinguished by sand size lenticular micaceous (?) grains, many bluish gray lenses of clayey material which pinch out, some of which show offset and display "flame-like" structures, dips from 0° to 90°, some intensely fractured zones, and slickensides on many fractured surfaces, moderately weathered. ML		64	[illegible]	
552					
553					
554					
555	SILTSTONE, upper 1' of core intensely fractured with many slickensides and bluish gray clayey layers, from 555' to 556' a clayey zone with broken, angular siltstone particles mixed in, below this is another fracture zone followed by a contorted, jumbled siltstone zone, dips highly variable, some fine sandy lenses and offset bedding. ML		65	97%	
556					
557					
558			66	No Recovery	
559					
560					
561					
562					
563	SILTSTONE still highly fractured with may slickensides, much of the core consists of fractured siltstone particles with offset bedding and variable dips in a bluish gray clay matrix. ML				
564					
565			67	100%	
566					
567			68	94%	

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
568	SILTSTONE (Monterey Formation), olive black, 5YR2/1, interbedded with bluish gray siltstone and occasional thin beds of claystone, siltstone beds range in dip from horizontal to 50°, fractures occur parallel to bedding planes, intermittent zones of contorted bedding with minor offset of beds, slickenside surfaces common, highly fractured in zones, moderately weathered. ML		68	0.4'	
569					
570					
571					
572					
573					
574					
575	SILTSTONE, bluish gray claystone beds become thicker, ranging from 1/16" to 1/2".		69	0.5'	
576					
577					
578					
579					
580	Lens of fine grained sand.				
581	Siltstone becoming less fractured.				
582					
583	SILTSTONE, bedding dip changes drastically from 50° to horizontal in 2' of core, at 584', bluish gray claystone beds are pinched out and slightly offset, siltstone becomes well indurated below 584', highly jointed, slickensides common. ML		70	[illegible]	
584					
585					
586					

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Project No. 41299I Field Log of Boring No. B-2 Sheet 32 of 40

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
587	SILTSTONE (Monterey Formation), olive black, 5YR2/1, interbedded with bluish gray claystone and sandstone, beds range from 1/16" to 1" thick, dips range from horizontal to 18°, no weathering, some jointing (vertical), occasional thin lenses of sand (ash?) at 590', layer of very well indurated sandstone, fish-scales seen at 594', highly polished bedding plane surfaces. ML				
588					
589					
590			71	80%	
591	Very well indurated sanstone at 589.6' to 590.4'				
592					
593					
594	SILTSTONE, beds dipping mostly 35°, with clay-filled joints. ML				
595					
596					
597					
598			72	100%	
599	Highly contorted bedding, bluish gray claystone prevalent in this zone, highly fractured, clay-filled joints.				
600					
601					
602					
603			73	98%	
604					
605					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
606	SILTSTONE (Monterey Formation), olive gray, 5YR4/1, interbedded with some fine sandstone and bluish gray claystone. Bedding from 1" to 7" thick with the interbeds less than 1" thick, dips are 35° to 40° with joints mostly parallel to bedding, some are vertical, occasional slickensides surfaces, well indurated with very little weathering. ML		73	100%	
607					
608					
609					
610					
611					
612	SILTSTONE, slightly fissile, bedding from 1" to 8" with a few thin clayey interbeds and fine sand beds, slightly fractured area from 616.5' to 617', with slickenside surfaces, dips at 40°, most fractures display slick surfaces. ML		74	100%	
613					
614					
615					
616					
617	SILTSTONE, slightly higher percentage of fine sand, slickenside surfaces on fractures, dips average 25°.				
618					
619					
620					
621					
622			75	100%	
623	SILTSTONE, light olive gray, 5YR5/2, some fine grained sand, silicified, moderately fractured with minor offset bedding, some visible forams, dips approximately 25°.				
624					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
625	SILTSTONE, light olive gray, 5YR5/2, some fine sand, very hard, silicified, moderately fractured, visible forams, dips 25°. ML				
626	SILTSTONE (Monterey Formation), light olive gray, 5YR5/2, interbedded with a few bluish gray clay lenses, highly fractured and contorted zone at 626' to 627', dips 20° above fractured zone and 35° below it, general fracture trend parallel to bedding with some slickenside surfaces, some joints near vertical, occasional pods or thin lenses of fine sand, well indurated, slightly weathered. ML		76	95%	
627					
628					
629					
630					
631					
632			77	[illegible]	
633					
634					
635			78		
636	SILTSTONE, olive gray-olive black, 5YR1/2, appears brecciated through the entire run, containing mostly angular fragments of siltstone in silty matrix, dip of fractures is 55° to 60°, one 2.5" to 3" zone of shearing @ 638.5', also a very light gray, N8, fine sandy layer, 1" or less thick @ 640.6'. ML				
637					
638			79	99%	
639	Numerous small pieces of siltstone at 639.8'.				
640	Numerous polished surfaces, mostly not well indurated.				
641					
642					
643					

Project No. 412991 Field Log of Boring No. B-2 Sheet [illegible] of [illegible]

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
644	SILTSTONE (Monterey Formation), olive gray-olive black, 5YR2/2, less brecciated, cemented layer @ 645.6', fractures with 55° to 60° dip. ML		80	89%	
645					
646					
647					
648					
649					
650	Intrusive with possible baked upper contact				
651					
652	SILTSTONE, olive black, 5YR2/1, becomes more dense and cemented, fractures are sub-horizontal, 65°, and vertical, lithologic changes at 653.4', 653.7', 654.2', 654.4', and 658.2', upper ones are light gray, N7, sandy beds, one at bottom is light bluish gray, 5B6/1, brecciated siltstone. ML		81	83%	
653					
654	Sample taken at 654' yields age of Louisian (Middle Miocene).				
655					
656					
657					
658					
659	Monterey Formation, basal unit consisting of glaucophane schist (low grade), dusky blue, 5PB3/2, sandy matrix with rounded quartz grains.		82	100	
660					
661					
662					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
663	BRECCIA, dark bluish gray, 5B4/1, low grade blue schist, very weathered/reworked.		83	779	
664					
665	BRECCIA, dark bluish gray, 5B4/1, core is less broken-more intact, pronounced brecciation, hard layer on top, material is possibly reworked.				
666					
667			84	778	
668					
669					
670					
671					
672	BRECCIA, (San Onofre Breccia), medium bluish gray, 5B5/1, core contains many angular clasts from sand size to clasts larger than the core diameter (2 1/2"), material is in a fine grained bluish gray chloritic matrix which is highly weathered, much difficulty in keeping core intact, clasts are mainly glaucoplane shist, with some muscovite, lepedolite, plagioclase, quartz, garnet, and pyrite, well developed schistosity in most fragments.				
673					
674			85	598	
675					
676					
677					
678			87	688	
679					
680			88	848	
681					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
682	BRECCIA (San Onofre Breccia), medium bluish gray, 5B5/1, many angular clasts ranging from sand-sized to 4" to 5" (larger than 2 1/2" core diameter) in a blue gray, fine grained chloritic matrix, generally moderately to highly weathered, most clasts display a well developed schistosity and contain glaucophane, muscovite, garnet, plagioclase, and pyrite.				
683			89	85%	
684					
685					
686					
687			90	80%	
688					
689			91	67%	
690					
691			92	91%	
692					
693	Clay matrix with clasts to 3".		93	100%	
694	Cores fracture easily. Most pieces less than 2" long.		94	57%	
695			95	96%	
696					
697			96	83%	
698					
699			97	80%	
700					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
			98		
701	BRECCIA (San Onofre Breccia), medium bluish gray, 5B5/1, schistose clasts are contained in a light bluish gray cholorite matrix in various degrees of weathering clasts vary in size from sand size (medium grained) to larger than core size, clasts are mostly chlorite and glaucophane schist, 55° fracture surface dip.		99	76%	
702					
703					
704					
705			101	64%	
706					
707			104	25%	
708					
709	Minerals embedded in matrix include quartz, biotite, garnets, amphibole, and glaucophane schist clasts.				
710			105	67%	
711					
712					
713			106	76%	
714					
715			108	27%	
716					
717			109		
718			110	12%	
719					

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
720 721 722	Only clasts recovered, no matrix. Clasts are angular, blue schists with garnet, biotite, pyrite, quartz, porphyroblasts, from pebble size to 3". Clasts are fairly fresh.		110	12ft	
723	One fresh blue schist clast recovered.		111	5ft	
724 725 726 727	BRECCIA (San Onofre Breccia), medium bluish gray, 5B5/1, matrix supporting angular to rounded, generally metamorphic clasts from sand size to clasts longer than 2 1/2", poorly to moderately cemented matrix, matrix and clasts fresh, no orientation, sorting, or stratification to clasts within matrix, matrix is fine grained chlorite material.		112	96%	30%
728 729 730 731 732	BRECCIA, highly fractured to massive, well indurated clasts to 5" or more in length.		113	90%	48%
733 734 735 736 737 738	BRECCIA, bluish gray matrix with rounded to angular clasts. Friable to well indurated, moderately fractured.		114	100%	66%

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DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
739	BRECCIA (San Onofre Breccia), medium bluish gray, 5B5/1, chloritic clay matrix contains more sand than before, moderate to well cemented with clasts ranging in size from sand size to larger than core barrel size, clasts are angular to subangular, larger clasts are mostly chlorite and glaucophane schist, smaller clasts of quartzite, and amphibole, some lenses of poorly indurated medium grained sandstone, joints at 35°, moderately weathered in zones, well indurated at 740.5' to 743'.		115	100%	71%
740					
741					
742					
743					
744					
745	Clast is faulted and displaced 1/2".		116	75%	0%
746			117	100%	
747					
748					
749					
750	Bottom of Boring at 749.5 ft.				

2.5I-165

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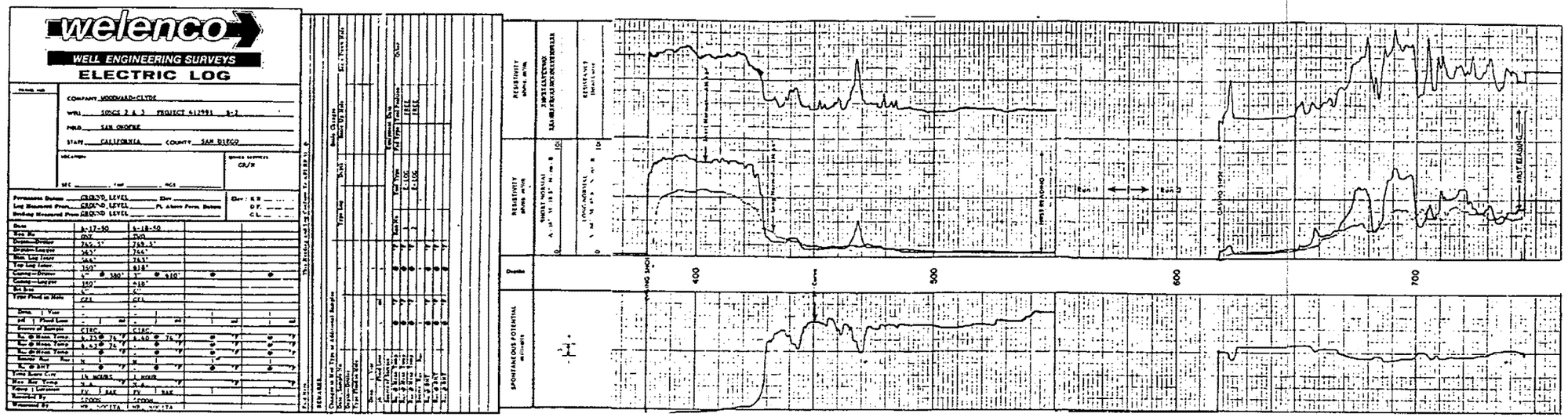
APPENDIX 1-B

GEOPHYSICAL LOGS



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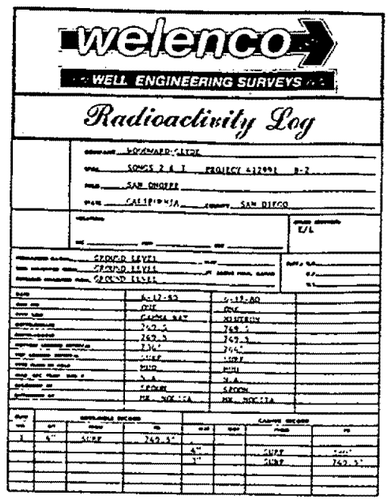
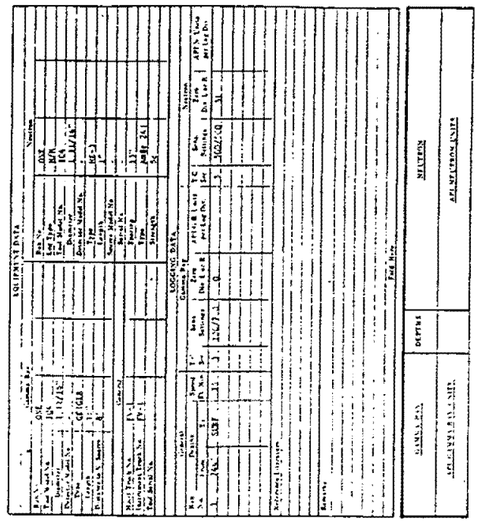
ELECTRIC LOG

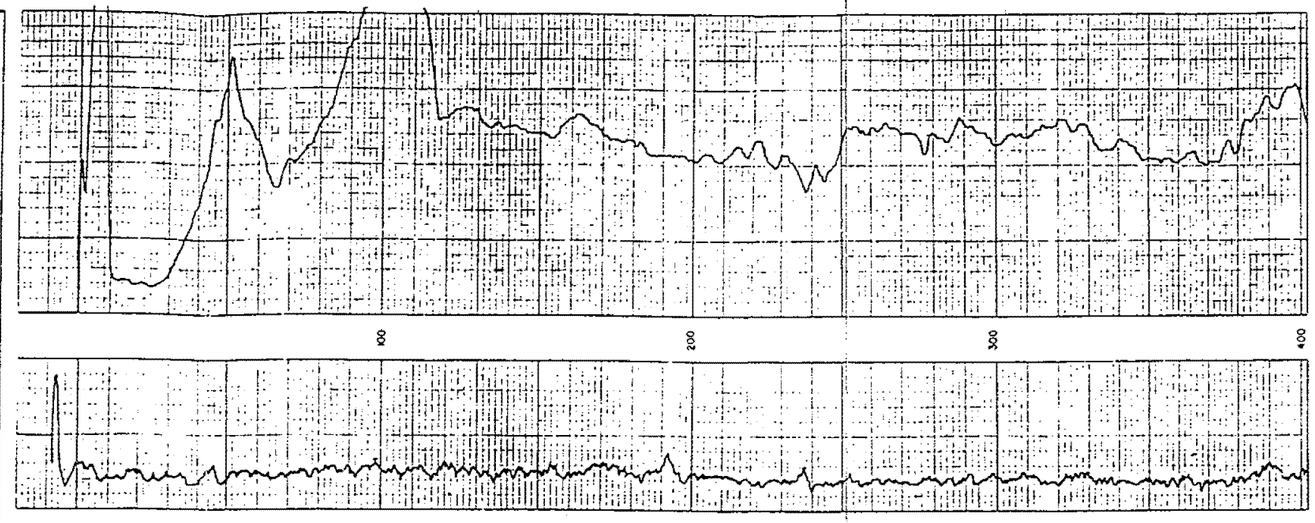
Project No. 412991

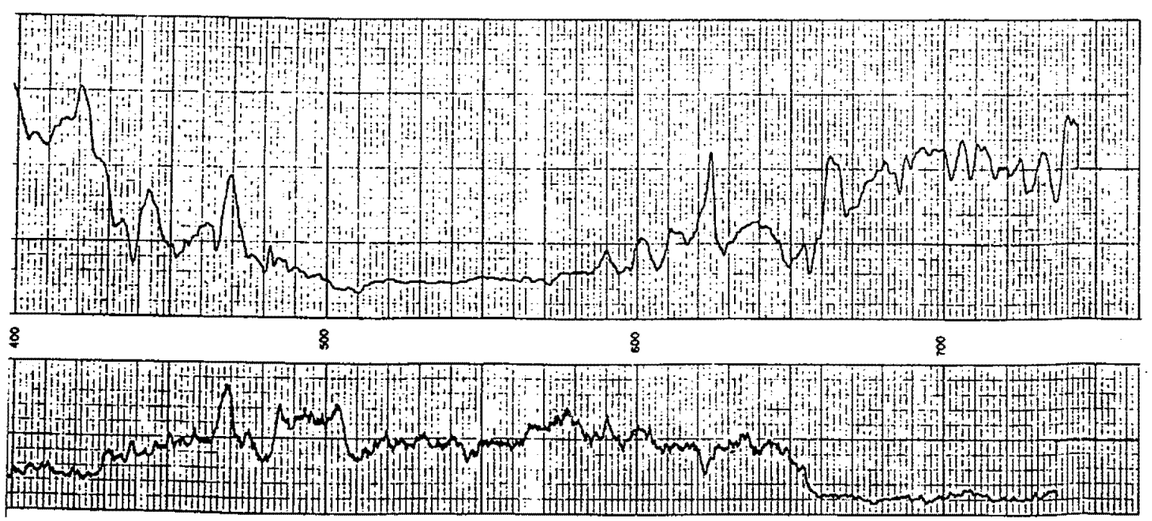
SONGS 2 & 3

Fig. 1-B-1









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RADIOACTIVITY LOG

Project No. 412991

SONGS 2 & 3

Fig. 1-B-2

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APPENDIX 1-C

MICROFOSSIL AGE DATES

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July 3, 1980

TO: Southern California Edison Co.

RE: So. Cal. Edison
Core B-1, Samples 1 to 5
San Onofre Area
Orange County, California

NANNOFOSSIL REPORT

Introduction

Four (4) samples were examined for calcareous and siliceous nannofossils and siliceous microfossils. These samples represent scattered depth intervals from near 485 feet to about 654 feet cored in this test hole and provide the basis for the age determinations of this report.

The initial preparations of the four samples were void of calcareous nannofossils but did contain fragments and parts of siliceous microfossils (siliceous spicules, spines and radiolarian parts). The samples were then treated and prepared specifically for siliceous microfossils and on examination, were found to contain reasonably diverse assemblages of siliceous microfossils. Though the majority of diatom species present are benthonic forms, the assemblages do contain some pelagic species along with silicoflagellates, which allow the placement of these samples into their representative biostratigraphic zones. The high ratio of benthonic to planktonic forms suggest the marine environment

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during the deposition of these materials was moderately shallow, probably neritic or a continental shelf setting.

The provincial ages of each of these samples are given in the following stratigraphic summary and are based on the included siliceous microfossils or siliceous nannofossils. The age and zonation framework used is based on the data and definitions provided by Barron (1975, a-b) and Koizumi (1975, 1977) for the diatoms and from Bukry (1975) and Ling (1977) for the silicoflagellates. A limited list of species of the total number identified from each of the samples is included as support for the age determinations. This suite of species given as representative of each sample include the age diagnostic forms and the more common species observed in each sample. The frequency or abundance of each species is also noted by letter symbols. The key to these symbols are as follows: V = very rare, R = rare, S = sparse, F = frequent.

Stratigraphic Summary

485' 4-8" (sample 3)

AGE:	Late Miocene, near the top of the lower Mohnian
DIATOM ZONE:	Denticula hustedtii/D. lauta, uppermost part
SILICOFLAGELLATE ZONE:	Distephanus longispinus, uppermost part

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485' 4-8" (sample 3) (con't.)

DISCUSSION: Selected species occurring in this sample include Actinocyclus ingens (V), Actinoptychus gruendleri (V), Coscinodiscus gigas diorama (V), C. marginatus (F), C. robustus (V), Cyclotella kelloggi (V), Denticula hustedtii (R, including narrow ended form), D. lauta (V), Distephanus longispinus (V, with angled basal ring), Lithodesmium minusculum (V), Opephora schwartzii (S), Endictya japonica (V), Rhabdonema japonicum var. sparcicostatum (V), Stephanopyxis schenckii (S).

491' 24-37" (sample 1)

AGE:	Late Miocene, lower Mohnian
DIATOM ZONE:	Denticula hustedtii/D. lauta
SILICOFLAGELLATE ZONE:	Distephanus longispinus, lower part or "Mesocena hexagona subzone"

DISCUSSION: Some of the species present here include Actinocyclus ingens (S), A. tsugaruensis (S), Actinoptychus gruendleri (V), Arachnoidiscus decoratus (F), Bruniopsis mirabilis (V), Coscinodiscus marginatus (S), C. robustus (R), C. vestustissimus (V), Cyclotella kelloggi (R), Denticula hustedtii (S), D. lauta (V), Distephanus longispinus (R, with rounded basal ring), Endictya japonica (R), Melosira sulcata (F), Mesocena hexagona (R), M. septenaria (R), Stephanopyxis schenckii (V).

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491' 50-55" (sample 2)

AGE:	Late Miocene, lower Mohnian
DIATOM ZONE:	Denticula hustedtii/D. lauta
SILICOFLAGELLATE ZONE:	Distephanus longispinus, lower part or "Mesocena hexagona sub-zone"

DISCUSSION: Distinctive or more common species here include Actinocyclus ingens (R), A. tsugaruensis (R), Actinoptychus gruendleri (V), Arachnoidiscus decoratus (R), Cannopilus schulzii var. longispinus (V), Coscinodiscus gigas diorama (V), C. marginatus (S), C. robustus (R), Cyclotella kelloggi (V), Denticula hustedtii (V), D. lauta (V), Distephanus longispinus (V), D. parva (V), Endictya japonica (V), Melosira sulcata (F), Mesocena hexagona (V), M. septenaria (V), Stephanopyxis schenckii (R).

650.3' 43-46" (sample 5)

AGE:	Middle Miocene, Luisian
DIATOM ZONE:	Denticula lauta
SILICOFLAGELLATE ZONE:	Corbisema triacantha

DISCUSSION: Miocene radiolarians were noted in this sample in addition to the diatoms and silicoflagellates. Selected representative species of all the siliceous forms include Actinocyclus ingens (F), A. i. var nodus (F), A. tsugaruensis (S), Actinoptychus gruendleri (V), Cannopilus boliviensis major (R), C. hemisphaericus (V),

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650.3' 43-46" (sample 5)(con't.)

DISCUSSION (con't.):

Clathrocyclas sp. (V), Corbisema cf. triacantha (R), Coscinodiscus endoi (V), C. marginatus (F), C. robustus (R), Denticula lauta (R), Dictyocha epiodon (V), Diploneis crabro (S), Distephanus parva (F), Dorcadospyris sp. aff. pannosa (R), Endictya japonica (S), Hemiaulis polymorphus (V), Isthmia nervosa (F), Lamprocyrtis hannai (R), Larnacantha polyacantha (R), Liriospyris reticulata (V), Phorticium regulare (V), Spongodiscus spp. (F), Stephanogonia hanzawae (V), S. polyacantha (V), Stephanopyxis turris s.l. (V), Stylacontarium cf. bispiculum (R), Synedra jouseana (V), Xanthopyxis lacera (R).

Interpreted by:

E. Dean Milow

E. Dean Milow

ANDERSON, WARREN & ASSOCIATES, INC.

A. D. Warren

A. D. Warren

RE: Southern Calif. Edison - Core B-1, San Onofre Area

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ANDERSON, WARREN & ASSOCIATES, INC.
CONSULTING MICROPALEONTOLOGY
11526 Sorrento Valley Road Suite G
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(714) 755-1524
TWX: 9103221735 MICROPALEO SDG

July 3, 1980

TO: Southern California Edison Co.

RE: So. Calif. Edison
Corehole B-1 Cores
San Onofre Area
Orange County, California

FORAMINIFERAL REPORT

This report is based on processing and analysis of 5 core samples received June 18, 1980 on a rush priority basis.

Results of this study are detailed as follows:

Sample #1 (491'+24-26", +29-31", +35-37")

Barren of Foraminifera. Fish debris (C), spicules (R). Processed residue consists of few shale particles in the coarse fraction and very fine-grained, clear, angular quartz sand abundant in the fine fraction.

AGE: Possibly provincial Late Miocene (based on lithology and organic remains)

ENVIRONMENT: Marine undifferentiated

Sample #2 (491'+50-55")

Barren of Foraminifera. Fish debris CA, spicules RF, statocysts F. Lithology of processed residue same as sample #1.

AGE: Possibly provincial Late Miocene (based on lithology and organic remains)

ENVIRONMENT: Marine undifferentiated

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RE: Southern Calif. Edison - Core B-1, San Onofre Area

Sample #3 (485'+4-8")

Barren of Foraminifera. Diatoms F. Tan dolomitic limestone with few diatoms locked in the matrix.

AGE: Indeterminate

ENVIRONMENT: Marine undifferentiated

Sample #4 (470'+26-30")

Bolivina marginata var. F, B. vaughani F, B. sp. FC, Bulimina uvigerinaformis F, Buliminella brevior R, Eponides rosaformis R, Pulvinulinella subperuviana FC, Uvigerina angelina R. Diatoms F, fish debris F, radiolaria F, spicules F. Silty, micaceous shale.

AGE: Provincial Late Miocene, Early Mohnian Stage

ENVIRONMENT: Outer Neritic to Upper Bathyal

Sample #5 (650.3'+43-46")

Bolivina advena(?) molds F, Dentalina obliqua(?) molds R, Pullenia miocenica(?) molds F, Siphogenerina(?) sp. molds R, Uvigerinid molds R, Valvulineria californica(?) molds C. Diatoms F. Brown to tan dolomitic limestone full of foraminiferal molds with test material very badly leached. Some molds are of possible Middle Miocene Foraminifera.

AGE: Probably provincial Middle Miocene, Middle Luisian Stage or older

ENVIRONMENT: Outer Neritic to Upper Bathyal or deeper

ANDERSON, WARREN & ASSOCIATES, INC.

A. D. Warren

2.5I-177

APPENDIX 2-A

LOGS OF VIBRATORY CORES

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Project No. 41299I Field Log of Boring No. 1-1 Sheet 1 of 2

BORING LOCATION SONGS OFFSHORE - E-1,597,186; N-427,655		ELEVATION AND DATUM Water Depth 72'	
DRILLING AGENCY WCC	DRILLER Iverson	DATE STARTED 6-7-80	DATE FINISHED 6-8-80
DRILLING EQUIPMENT		COMPLETION DEPTH 25.5'	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Plastic		NO OF SAMPLES DIST.	UNDIST. CORE
DRILLING METHOD VIBRATORY CORE		WATER ELEV. FIRST	COMPL. 24 HRS.
CORE BARREL	LENGTH	BIT	LOGGED BY: CHECKED BY:

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	Sample No.
1	Sand, dark greenish gray, 5GY4/1, very fine grained, well sorted, micaceous, organic odor, random shell fragments and some complete shells (sample 1 taken at 2.2'). SP		1		
2					1
3					
4					
5					
6					
7			2		
8					
9					
10					
11					
12					
13					
14					
15					
16					

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Project No. 41299I Field Log of Boring No. 1-1 Sheet 2 of 2

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	RQD
	Age = 8,510 ± 265 yrs.				
	Sand, dark greenish gray, 5GY4/1, very fine grained, well sorted, micaceous, occasional pebbles. SP				2
17					
18	Abundant shells and shell fragments from 15.8' to 16.5'.				
19	Grades to medium grained sand at 17.8'.				
20	Grades to coarse grained sand at 19.0', light yellowish gray, 5Y6/2, subangular grains, moderately well sorted, occasional pebbles. SP		2		
21					
22	Grades to medium grained sand, medium gray, N5, well sorted Clay at 22.4', greenish black, 5G2/1, very plastic and sticky. CL				
23					
24	Sand at 24', dark greenish gray, 5GY4/1, fine grained, slightly clayey. SC				
25					
26	Bottom of Hole at 25.5'				
27					
28					
29					
30					
31					
32					
33					
34					
35					

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Project No. 41299I Field Log of Boring No. 1-2 Sheet 1 of 3

BORING LOCATION SONGS OFFSHORE - E-1,595,807; N-426,123		ELEVATION AND DATUM Water Depth 100'	
DRILLING AGENCY WCC	DRILLER Iverson	DATE STARTED 6-8-80	DATE FINISHED 6-9-80
DRILLING EQUIPMENT		COMPLETION DEPTH 39.5'	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Plastic		NO OF SAMPLES: DIST.	UNDIST. / CORE
DRILLING METHOD VIBRATORY CORE		WATER ELEV. FIRST	COMPL. / 24 HRS.
CORE BARREL / LENGTH / BIT		LOGGED BY: JW/BK	CHECKED BY:

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
1	SAND, dark greenish gray, 5GY4/1, very fine grained, well sorted, micaceous, random shell fragments and some whole shells. SP		1		
2					
3					
4					
5					
6					
7					
8					
9	Broken, nearly complete, pelecypod shell at 9.2'.				3
10					
11	Complete gastropod at 11.4'.				4
12					
13					
14	Shells and shell fragments at 14.5'.				5
15					
16					

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Project No. 41299I Field Log of Boring No. 1-2 Sheet 2 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
	SAND, dark greenish gray, 5GY4/1, very fine grained, well sorted, micaceous, very slightly clayey. SP				
17			1		
18					
19	Pebbles, shells, and shell fragments from 19.6' to 20.0'. Age = 9,095 ± 335 yrs.				
20	Charcoal fragments and a pelecypod at 20.7'.				6
					5
21					
22					
23					
24	Becomes fine grained at 23.7'. Large pebbles at 23.9'. Becomes fine to medium grained at 24'.				
25	Rounded pebbles at 25.4'. Becomes coarse grained at 25.5'.				
26	Becomes fine grained at 25.9'.				
27	Becomes medium grained at 27.1'. Becomes fine grained at 27.5'.		2		
28	Becomes fine to medium grained at 27.7'.				
29					
30	SAND, olive gray, 5YR4/2, fine to medium grained, sub-angular, well sorted, micaceous. SP				
31	SAND, olive gray, 5YR4/2, fine grained, well sorted, micaceous. SP				
32					
33	Grades to fine medium grained at 33.4'				
34	Grades to fine grained at 33.7'				
35					

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Project No. 41299I Field Log of Boring No. 1-2 Sheet 3 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	Sample No.
	SAND, olive gray, 5YR4/2, fine grained, micaceous. SP				
36	Grades to medium grained at 36.3'.				
	Abrupt change to fine grained at 36.7'.				
37	Rounded pebble (3/8") at 37.4'.		3		
38					
	No recovery from 38.5 to 39.5'.				
39					
40	End of hole. 1-2				

Project No. 41299I Field Log of Boring No. 1-3 Sheet 1 of 3

BORING LOCATION SONGS OFFSHORE - E-1,594,479; N-424,709		ELEVATION AND DATUM Water Depth 125'	
DRILLING AGENCY WCC	DRILLER Iverson	DATE STARTED 6-10-80	DATE FINISHED 6-10-80
DRILLING EQUIPMENT		COMPLETION DEPTH 39.5'	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Plastic		NO OF SAMPLES: DIST.	UNDIST. / CORE
DRILLING METHOD VIBRATORY CORE		WATER ELEV. / FIRST	COMPL. / 24 HRS.
CORE BARREL / LENGTH / BIT		LOGGED BY: JW/BN	CHECKED BY:

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
1	SAND, silty, dark greenish gray, 5GY4/1, very fine grained, micaceous, random shell fragments. SM				
2					
3					
4	Abundant shells and shell fragments.				8
5					
6					
7			1		
8					
9	scattered shells				9
10					
11					
12					
13					
14					
15					
16					

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Project No. 412491 Field Log of Boring No. 1-3 Sheet 2 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
17	SAND, silty, dark greenish gray, 5GY4/1, very fine grained, micaceous, random shell fragments. SM				10
18					
	organic matter		1		
19					11
	organic matter, shells				
20					13
21					
	crab leg				
22			2		12
23					
	Age = 9,400 ± 300 yrs.				
24					14
	no recovery at 24.0' to 25.0'.				
25					
	gastropod, pelecypod				
26	Age = 5,065 ± 180 yrs.				15
	becomes fine grained				
27					
28			3		
29					
30					
31	no recovery at 30.8' to 31.0'.				
32					
33					
34			4		
35	SAND, dark gray N3, fine grained, well sorted, micaceous, small laminae of mica. SP				

Project No. 41299I Field Log of Boring No. 1-3 Sheet 3 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
36					
37					
38	Gradational change to clayey silt, grayish black, N2.		4		
39	Clayey silt, olive black, 5YR2/1, slightly micaceous. ML				
40	Bottom of hole. 1-3				

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Project No. 41299I Field Log of Boring No. 1-4 Sheet 1 of 3

BORING LOCATION SONGS OFFSHORE - E-1,593,040; N-423,369		ELEVATION AND DATUM Water Depth 165'	
DRILLING AGENCY WCC	DRILLER Iverson	DATE STARTED 6-11-80	DATE FINISHED 6-12-80
DRILLING EQUIPMENT		COMPLETION DEPTH 39.5'	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Plastic		NO OF SAMPLES: DIST.	UNDIST. / CORE
DRILLING METHOD VIBRATORY CORE		WATER ELEV. / FIRST	COMPL. / 24 HRS.
CORE BARREL / LENGTH / BIT		LOGGED BY:	CHECKED BY:

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
	SAND, silty, olive black, 5Y2/1, very fine grained, micaceous, a few scattered shell fragments. SM				
1					
2	Shells and shell fragments at 2.2' to 2.6'.				16
3	Shells from 3.9' to 4.4'.				
4					17
5					
6	Shells at 6.1'.				18
7	Gastropods at 7.1'.				19
8			1		
9	Shells at 9.2'.				20
10					
11					
12	Organic matter at 12.1'.				21
13					
14					
15					
16					

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Project No. 41299I Field Log of Boring No. 1-4 Sheet 2 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
17	SAND, olive gray 5Y5/1, medium grained, subangular, moderately well sorted, scattered pebbles up to 1/4". SP		1		
18	SAND, olive gray 5Y4/1, fine to coarse grained, subangular, poorly sorted, slightly micaceous, SP, from 17.9 to 18.2.				
19	SAND, dark yellow gray 5Y7/1, medium to coarse grained, subangular, moderately sorted, occasional rounded pebbles to 3/4", SP, from 18.2' to 18.4'.				
20	SAND, olive gray, 5Y4/1, fine grained, moderately sorted, micaceous, some scattered pebbles. SP				
21	Organic matter at 21.1'. Age = 11, 355 ± 650 yrs.		2		22
22					
23					
24	Gastropod at 24.6'.				23
25	Concentration of rounded pebbles up to 1" from 25.0' to 25.4'.		3		
26					
27					
28					
29					
30					
31					
32	SAND, medium light gray, N6, as above with small blebs and discontinuous lenses of sand which contain little mica.		4		
33	Slightly coarser grained, interval from 33.0' to 33.6'.				
34					
35					

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Project No. 412991 Field Log of Boring No. 1-4 Sheet 3 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	Sample No.
	SAND, olive gray, 5Y4/1, fine grained, subangular, well sorted, micaceous. SP				
36	Small rounded pebbles at 36.3'.				
37	Scattered shell fragments at 37.3'.		4		
38					
39					
40	Bottom of Hole 1-4 at 39.5'.				

Project No. 41299I Field Log of Boring No. 1-5 Sheet 1 of 3

BORING LOCATION SONGS OFFSHORE - E-1,591,165; N-421,269		ELEVATION AND DATUM Water Depth 200'	
DRILLING AGENCY WCC	DRILLER Iverson	DATE STARTED 6-12-80	DATE FINISHED 6-12-80
DRILLING EQUIPMENT		COMPLETION DEPTH	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Plastic		NO OF SAMPLES: DIST.	UNDIST. / CORE
DRILLING METHOD VIBRATORY CORE		WATER ELEV. FIRST	COMPL. / 24 HRS.
CORE BARREL / LENGTH / BIT		LOGGED BY: JW/BN	CHECKED BY:

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
1	SAND, silty, olive gray, 5YR3/2, very fine grained, micaceous, scattered shell fragments. SM		1		
2					
3					
4					
5					
6					
7					
8	Organic debris at 7.9' Gradual color change to olive black, 5YR2/1, from 8.0' to 8.5'.				25
9					
10					
11					
12					
13					
14					
15					
16					

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Project No. 41299I Field Log of Boring No. 1-5 Sheet 2 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	Sample No.
	SAND, silty, olive black, 5YR2/1, very fine grained, micaceous, scattered shell fragments. SM				
17					
18					
19			1		
20					
21					
	No recovery from 21.5' to 22.0'.				
22	Scattered organic debris from 22.0' to 27.0'.				
23					
24	Organic matter at 23.9'.				26
25					
26			2		
27					
28					
	Organic matter at 29.7'.				
29					
30					27
	Organic matter at 30.6'. Age = 13,160 ± 550 yrs.				28
31					
32					
33					
34	Organic matter at 33.8'.		3		29
35					

Project No. 41299I Field Log of Boring No. 1-5 Sheet 3 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE Sketch	Run No.	Recov. ft.	Sample No.
	SAND, silty, olive black, 5YR2/1, very fine grained, micaceous, scattered shell fragments. SM		3		
36					
37					
38	Organic matter in concretion at 38.4'.		4		
	Organic matter at 38.5'. Age = 12,270 ± 340 yrs.				32 31
39					
40	Bottom of hole 1-5 at 39.5'.				

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Project No. 41299I Field Log of Boring No. 2-1 Sheet 1 of 3

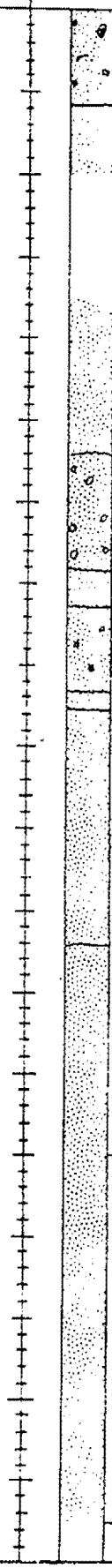
BORING LOCATION SONGS OFFSHORE - E-1,597,740; N-418,851		ELEVATION AND DATUM Water Depth 165'	
DRILLING AGENCY WCC	DRILLER Iverson	DATE STARTED 6-13-80	DATE FINISHED 6-14-80
DRILLING EQUIPMENT		COMPLETION DEPTH 44.1'	ROCK DEPTH
SIZE AND TYPE OF CASING 4" Casing		NO OF SAMPLES: DIST.	UNDIST. / CORE
DRILLING METHOD VIBRATORY CORE		WATER ELEV. FIRST	COMPL. / 24 HRS.
CORE BARREL / LENGTH / BIT		LOGGED BY: JW/BH	CHECKED BY:

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
1	SAND, silty, olive gray, 5YR3/2, very fine to fine grained, subangular, micaceous, random shell fragments. SM				
2					
3					
4					
5					
6					
7			1		
8					
9					
10					
11					
12					
13					
14					
15	SAND, olive gray, 5YR4/2, medium to coarse grained, subangular, moderately sorted, slightly micaceous, shell fragments. SP				
16	SAND, olive gray, 5YR3/2, fine grained, subangular, poorly to moderately sorted, slightly silty, micaceous. SP				

Project No. 41299I Field Log of Boring No. 2-1 Sheet 2 of 3

DEPTH (FEET)	DESCRIPTION
	Starting at 15.7' -
17	SAND, olive gray, 5YR4/2, medium to coarse grained, sub-angular, moderately to poorly sorted, slightly micaceous, numerous shell fragments, numerous rounded pebbles. SP.
18	SAND, olive gray at 17.1', 5YR4/1, fine grained, subangular, well sorted, micaceous. SP
19	no recovery at 18.0' to 19.5'.
20	
21	SAND, olive gray, 5YR4/2, medium to coarse grained, sub-angular, moderately sorted, micaceous, numerous rounded pebbles to 1 1/2" in diameter. SP
22	SAND, olive gray, 5YR4/1, fine grained, subangular, well sorted, micaceous. SP
23	SAND, olive gray, 5YR4/2, medium grained, subangular, well sorted, micaceous, occasional sub-rounded pebbles to 1/4" in diameter. SP
24	SAND, olive gray at 24.3' to 24.5', 5YR4/1, fine grained, subangular, well sorted, micaceous. SP
25	SAND, olive gray, at 24.5', 5YR4/2, medium grained, sub-angular, well sorted, micaceous. SP
26	SAND at 25.2' becomes fine to medium grained.
27	SAND, olive gray, 5YR4/1, fine grained, subangular, well sorted, micaceous. SP
28	
29	From 28.7' to 29.3' vertical stringers of coarse grained sand.
30	
31	Organic matter.
32	
33	
34	no recovery at 34.5' to 35.0'
35	

ROCK CORE



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Project No. 41299I Field Log of Boring No. 2-1 Sheet 3 of 3

DEPTH (FEET)	DESCRIPTION	ROCK CORE: Sketch	Run No.	Recov. ft.	Sample No.
	SAND, olive gray, 5YR4/1, fine grained, subangular, well sorted, micaceous. SP				
36	From 36.2' to 38.2' - blebs of whitish sand deficient in mica, up to 1/2" in diameter.				
37			4		
38					
39	no recovery at 39.3' to 40.0'.				
40					
41					
42			5		
43					
44					
	Bottom of hole 2-1 at 44.1'.				

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APPENDIX 2-B

AGE DATING RESULTS

Amended: April 2009 TL: E048000

APPENDIX 2-B

SUMMARY OF AGE DATING ANALYSES

The results of radiocarbon age determinations performed on selected samples of shell and organic material obtained in cores from vibratory drilling offshore of SONGS Units 2 and 3 are attached in this Appendix. Specifically, Table 2B-1 summarizes radiocarbon age date determinations on seven samples. This table is followed by the specific data sheets for each sample for the determinations made by Krueger Enterprises, Inc., Geochron Laboratories Division located in Cambridge, Massachusetts. It is noted that the results for Sample 15 of Core 1-3 appear anomalous when compared to the other results. Also, the quantity of sample was noted to be small enabling only limited pretreatment. Based on a discussion with Mr. Krueger, who made the determination, if this date were in error, it would be too young. For these reasons, it is suggested that the results of Sample 15 of Core 1-3 may be treated as anomalous and, therefore, disregarded in analysis.

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TABLE 2B-1

SUMMARY OF AGE DATING RESULTS

Core No.	Sample No.	Depth (ft)	Material Type	Age Date in Years Before Present*
1-1	2	16.4	Shells	8,510 ± 265
1-2	6	19.7	Shells	9,095 ± 335**
1-3	14	23.4	Organic	9,400 ± 300
1-3	15	25.7	Shells	5,065 ± 180**
1-4	22	21.1	Organic	11,355 ± 650
1-5	28	30.6	Organic	13,160 ± 550
1-5	31	38.5	Organic	12,270 ± 340

* These age dates are referenced to the year A.D. 1950.

** Thorough leaching not possible during pretreatment due to limited size of sample.

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KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

PRIORITY BASIS

RADIOCARBON AGE DETERMINATION **REPORT OF ANALYTICAL WORK**

Our Sample No. GX-7327 **Date Received:** 27 June 1980

Your Reference: Project 41299I, Task 3160 **Date Reported:** 7/7/80

Submitted by: O. S. Ghuman
Woodward-Clyde Consultants
4000 W. Chapman St.
Orange, CALIF 92668

Sample Name: Sample #2. Offshore SONGS. Boring 1-1, run 2, section C, 15.8-16.5'. Shells.

AGE = 8510 +/- 265 C-14 years B.P. (c-13 corrected)

Description: Small sample of marine shells of various species.

Pretreatment: Shells and shell fragments were recovered after disaggregating the sample with ultrasonics. The shell material was further cleaned and rinsed briefly with very dilute HCl to remove altered surface material. The cleaned shell material was then hydrolyzed under vacuum to recover carbon dioxide for the analysis.

Comment:

δC^{13}_{PDB} = +1.1 $^{o}/_{oo}$.

Notes: This date is based upon the Libby half life (5570 years) for C^{14}. The error stated is ±1 σ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

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PRIORITY BASIS

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. GX-7335 — **Date Received:** 30 June 1980

Your Reference: P.O. #41299I — **Date Reported:** 23 July 1980

Submitted by: O. S. Ghuman
Woodward-Clyde Consultants
4000 W. Chapman St.
Orange, Calif 92668

Project No. 41299I

Sample Name: Offshore SONGS. Sample #6.
Boring 1-2, run 1, sec. A, 19.8'. Shells

AGE = 9095 +/- 335 C-14 years B.P. (C-13 corrected)

Description: Mixed shell fragments in sand.

Pretreatment: The shells were cleaned thoroughly in an ultrasonic cleaner. A brief leaching with very dilute HCl was utilized to remove additional surficial material which may have been altered. Thorough leaching was not possible without severely reducing the size of the sample. The cleaned shells were then hydrolyzed with HCl, under vacuum, and the carbon dioxide recovered for the analysis.

Comment:

δC^{13}_{PDB} = +1.4 ‰

Notes: This date is based upon the Libby half life (5570 years) for C^{14}. The error stated is $\pm 1\,\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

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GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

PRIORITY BASIS

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. GX-7328 — **Date Received:** 27 June 1980

Your Reference: Project 41299I, Task 3160 — **Date Reported:** 2 July 1980

Submitted by: O. S. Ghuman
Woodward-Clyde Consultants
4000 W. Chapman St.
Orange, CALIF 92668

Sample Name: Sample # 14. Offshore SONGS. Boring 1-3, run 2, section A, 23.4 feet.

AGE = 9400 ± 300 C-14 years B.P.

Description: Small sample of organic matter in marine sediment.

Pretreatment: The entire sample was dispersed in a large volume of water and the clays and organic matter were eluted away from any sand and silt by sedimentation and decantation. The clay/organic fraction was then treated with hot dilute HCl to remove any carbonates. It was then filtered, washed, dried, and roasted in oxygen to recover carbon dioxide from the organic matter for the analysis.

Comment:

δC^{13}_{PDB} = ‰.

Notes: This date is based upon the Libby half life (5570 years) for C^{14}. The error stated is ±1 σ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

Amended: April 2009 TL: E048000

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PRIORITY BASIS

RADIOCARBON AGE DETERMINATION — **REPORT OF ANALYTICAL WORK**

Our Sample No. GX-7336 — **Date Received:** 30 June 1980

Your Reference: P.O. #41299I — **Date Reported:** 23 July 1980

Submitted by: O. S. Ghuman
Woodward-Clyde Consultants
4000 W. Chapman St.
Orange, Calif 92668

Project No. 41299I

Sample Name: Offshore SONGS. Sample #15.
Boring 1-3, run 3, sec. B. Shells.

AGE = 5065 +/- 180 C-14 years B.P. (C-13 corrected)

Description: Mixed shell fragments in sand.

Pretreatment: The shells were cleaned thoroughly in an ultrasonic cleaner. A brief leaching with very dilute HCl was utilized to remove additional surficial material which may have been altered. Thorough leaching was not possible without severely reducing the size of the sample. The cleaned shells were then hydrolyzed with HCl, under vacuum, and the carbon dioxide recovered for the analysis.

Comment:

δC^{13}_{PDB} = +0.9 ‰

Notes: This date is based upon the Libby half life (5570 years) for C^{14}. The error stated is ±1 σ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

Amended: April 2009 TL: E048000

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PRIORITY BASIS

RADIOCARBON AGE DETERMINATION **REPORT OF ANALYTICAL WORK**

Our Sample No. GX-7329 **Date Received:** 27 June 1980

Your Reference: Project 41299I, Task 3160 **Date Reported:** 7/7/80

Submitted by: O. S. Ghuman
Woodward-Clyde Consultants
4000 W. Chapman St.
Orange, CALIF 92668

Sample Name: Sample # 22. Offshore SONGS. Boring 1-4, run 2, section A, 21.1'. Organic carbon.

AGE = 11,355 +/- 650 C-14 years B. P.

Description: Small sample of organic matter in marine sediment.

Pretreatment: The entire sample was dispersed in a large volume of water and the clays and organic matter were eluted away from any sand and silt by sedimentation and decantation. The clay/organic fraction was then treated with hot dilute HCl to remove any carbonates. It was then filtered, washed, dried, and roasted in oxygen to recover carbon dioxide from the organic matter for the analysis.

Comment: The sample was quite small, but was counted on each of two days with good concordance, average reported.

δC^{13}_{PDB} = ‰.

Notes: This date is based upon the Libby half life (5570 years) for C^{14}. The error stated is ± 1 σ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

Amended: April 2009 TL: E048000

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PRIORITY BASIS
RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX-7337

Date Received: 30 June 1980

Your Reference: P.O. #41299I

Date Reported: @$ July 1980

Submitted by: O. S. Ghuman
Woodward-Clyde Consultants
4000 W. Chapman St.
Orange, Calif 92668

Sample Name: Offshore SONGS. Sample #28. Boring 1-5, run 2, sec A, 30.6'. Organic matter.

AGE = 13,160 +/- 550 C-14 years B.P.

Description: Organic matter from marine sediment.

Pretreatment: The entire sample was dispersed in a large volume of water and the clays and organic matter were eluted away from any sand and silt by sedimentation and decantation. The clay/organic fraction was then treated with hot dilute HCl to remove any carbonates. It was then filtered, washed, dried, and roasted in oxygen to recover carbon dioxide from the organic matter for the analysis.

Comment:

δC^{13}_{PDB} = ‰.

Notes: This date is based upon the Libby half life (5570 years) for C^{14}. The error stated is $\pm 1\,\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

Amended: April 2009 TL: E048000

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PRIORITY BASIS
RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX-7338

Date Received: 30 June 1980

Your Reference: P.O. #41299I

Date Reported: 24 July 1980

Submitted by: O. S. Ghuman
Woodward-Clyde Consultants
4000 W. Chapman St.
Orange, Calif 92668

Sample Name: Offshore SONGS. Sample #31. Boring 1-5, run 4, sec A, 38.5. Organic matter.

AGE = 12,270 +/- 340 C-14 years B.P.

Description: Organic matter from marine sediment.

Pretreatment: The entire sample was dispersed in a large volume of water and the clays and organic matter were eluted away from any sand and silt by sedimentation and decantation. The clay/organic fraction was then treated with hot dilute HCl to remove any carbonates. It was then filtered, washed, dried, and roasted in oxygen to recover carbon dioxide from the organic matter for the analysis.

Comment:

δC^{13}_{PDB} = ‰.

Notes: This date is based upon the Libby half life (5570 years) for C^{14}. The error stated is $\pm 1\,\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

Amended: April 2009 TL: E048000

APPENDIX 2.5J

ANALYSIS OF POST-1975 EARTHQUAKE ACTIVITY.

Site File Copy

Site File Copy

APPENDIX 2.5J

ANALYSIS OF POST 1975 EARTHQUAKE ACTIVITY

2.5J.1 POST-1975 EARTHQUAKE ACTIVITY WITHIN A 200-MILE RADIUS

In this appendix, the post-1975 earthquake activity (January 1975 through September 1979) of magnitude greater than 3.0 is summarized and compared to the preceding reports of activity in the 200-mile region around the site. No significant change in the activity pattern is noted. Data were obtained from the unpublished data file of the California Institute of Technology; these data are in the same form as those reported by Hileman and others (1973). Although the instrumentation coverage within the California Institute of Technology network is sufficient to provide locations of earthquakes of about magnitude 3 and larger within the onshore U.S. portion study area, detection and locations for activity for offshore and in Mexico as provided by the Caltech array is not necessarily complete and locations are probably less accurate. No better locations are known to be available for this time period, however, so the seismicity of Mexico is described in terms of the Caltech data. The magnitudes reported by the Caltech network are in M_L (local magnitude).

No earthquakes with $M_L \geq 6.0$ occurred during the post-1975 time period. Eight earthquakes occurred with $M_L \geq 5.0$ (see figure 2.5J-1). Four of these were in Mexico and four were in southern California in regions of known historic activity (Hileman and others, 1973; FSAR figure 2.5-20). None are closer than 70 miles from the site. In July 1975 one earthquake occurred between the San Miguel and Sierra Juarez fault zones with $M_L = 5.0$. This event is located near the 1974 Pino Solo earthquake ($M = 5.0$) (A. Nava, in preparation, Doctoral Dissertation, UCSD, referenced in Brune and others, 1979).

The seismicity with $M_L \geq 4$ is dispersed throughout southern California and Mexico (see figure 2.5J-2). The spatial distribution is generally similar to the 1932-1975 distribution of $M_L \geq 5$ earthquakes (FSAR figure 2.5-20), suggesting stability of seismic source regions for small earthquakes in time and space. The number of events for the 4-year period ($M_L \geq 4$) is roughly equivalent to the number $M \geq 5$ for the 43-year period, which is consistent with a frequency of $M \geq 4$ about 10 times greater than $M \geq 5$, as expected from the frequency-magnitude relationship $\text{Log } N = a - bM$ (Richter, 1958). The closest earthquake occurred about 45 miles SW from the site. In Mexico, the distribution of earthquakes $M \geq 4$ is oriented SW-NE, or perpendicular to the general trend of mapped faults. One earthquake, the August 19, 1978, Canon de la Presa event, has been relocated in a special study by Brune and others (1979). On the basis of that study, the true location is north of the Caltech location shown here; i.e., between the NE terminus of the San Miguel fault zone (as shown on the base map) and the City of Tijuana. The Caltech magnitude is M_L 4.1; Brune and others (1979) assign M_L 3.5. At the magnitude 4 level, no activity is associated with the Newport-Inglewood, Offshore Zone of

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Demarcation (OZD), or Rose Canyon fault zones in southern California. Two events occurred along the Whittier-Elsinore, and four events along the San Jacinto fault zones.

A low level of seismicity again prevails but is not entirely absent for earthquakes with $M_L \geq 3.0$ within 50 miles of the site (see figure 2.5J-3). The closest earthquake is about 9 miles NW of the site; a second is about 25 miles south. Activity occurs along the Newport-Inglewood fault zone (30 to 60 miles NW of the site) in the region of the aftershock zone of the 1933 Long Beach earthquake (Richter, 1958). Scattered activity is observed SE and SSE of the site but is not easily associated with known faults. Modest activity (seven events) is observed within about 25 miles of San Diego, but no earthquake is closer than 10 miles from the Rose Canyon fault. Substantial activity occurs between the southern half of the San Miguel and Sierra Juarez fault zones, between 50 and 100 miles SE of Tijuana.

In summary, the seismicity between January 1, 1975, and October 1, 1979, within 200 miles of the site is similar to the long term pattern for 1932 to 1975 and no distinctive, new patterns of activity are evident. Seismic activity suggests an apparent decrease westward between the San Andreas and San Jacinto faults and the hypothesized OZD. The offshore region is somewhat more active than the hypothesized OZD for the post-1975 period.

2.5J.2 RELATIONSHIP BETWEEN THE HYPOTHESIZED OZD AND OTHER MAJOR TOPOGRAPHIC FEATURES IN BAJA CALIFORNIA

Following is a discussion of the structural relationship of the major fault systems of Baja California and the possible structural and geomorphic continuity of these faults to the OZD. The geographic area to be described consists of the region of Baja California north of the Agua Blanca fault to the U.S.-Mexico Border and the region west of the Sierra Juarez to the Pacific Coast. Specific attention will be paid to the geologic and regional tectonic setting, the San Miguel fault zones, the Vallecitos fault zone, the Agua Blanca fault, and the possible connections between the San Miguel fault zone, the Vallecitos fault zone, and the hypothesized OZD.

Geologic Setting

The northwestern corner of Baja California can be divided into three physiographic and geologic provinces (see figure 2.5J-4):

A. A narrow coastal margin characterized by Tertiary marine and nonmarine sedimentary rocks and Tertiary-to-Holocene volcanic and volcanic-derived rocks

B. The gently seaward sloping foothills between the Pacific Coast and the central high peninsular ranges underlain by pre-batholithic eugeoclinal accumulations of volcanic and sedimentary rocks which were subsequently metamorphosed to varying degrees by intrusion of the batholith

C. The Peninsular Range of northeastern Baja California comprising middle Cretaceous plutonic rocks of the southern California batholith

Regional Tectonic Setting

Structurally, the western two-thirds of the northern part of Baja California consists of an uplifted and westwardly tilted fault block. The high eastern edge of the block is formed by the mountain ranges of the Sierra Juarez to the north and the Sierra San Pedro Martir to the south. Uplift of the eastern edge began about 10 million years ago (Gastil and others, 1975). The eastern escarpment was created by a series of east-dipping normal faults that downstep antithetic fault blocks towards the Gulf of California depression (Gastil and others, 1979).

The main structural block has been cut by three major fault zones: the Agua Blanca fault zone, the San Miguel fault zone, and the Vallecitos fault zone. The Agua Blanca fault zone trends westerly from its eastern limit in the Sierra Juarez to the Pacific coast south of Ensenada. Movement along the Agua Blanca system began during late Cretaceous time (Gastil and others, 1975).

The major northwest-trending faults of this region (the San Miguel and Vallecitos fault zones) and the adjacent continental borderland faults are believed to have been formed later in Middle Miocene time (Moore, 1969).

Generally, the principal fault systems of the northwest peninsula region are considered to be primarily strike-slip but many show evidence of dip-slip displacement as well. However, they do not appear to connect with the major dip-slip faults of the Sierra Juarez and Sierra San Pedro Martir.

The Agua Blanca fault zone is characterized by a relatively continuous main trace while the San Miguel and Vallecitos fault zones are characterized by en-echelon fault segments and associated shorter subparallel faults. Much shorter conjugate sets of left-lateral faults trend northeast across the region. Features along the two major northwest-trending fault zones suggest Quaternary activity. The major northwest and west trending faults are discussed separately below.

San Miguel Fault Zone

The San Miguel fault zone consists of two segments. In 1956, a 20-kilometer length of the southern segment broke along a series of short en-echelon ruptures (Shor and Roberts, 1958). Measured fault displacements ranged from 0 to 31 inches horizontally to 0 to 36 inches vertically; the sense of offset was uniformly right-lateral and down to the southwest. The southern segment is mapped as a principally dip-slip fault that dies out in the Sierra Juarez and does not connect with either the Agua Blanca fault or the dip-slip faults of the eastern escarpment (Gastil and others, 1975). There is no evidence that this fault offsets this escarpment or connects with faults in the Gulf of California.

The northwest end of the 1956 break lies en-echelon to the northern segment. The northern segment can be traced on air photos to the area northeast of Valle San Rafael where offset streams and dikes show right-lateral separation; the most clearly expressed fault trace appears to separate Mesozoic dikes only 100 meters (Gastil, 1975, 1979).

Vallecitos Fault Zone

The Vallecitos fault zone is en-echelon to the northern segment of the San Miguel fault zone, but separate from it by a distance of 6 to 10 kilometers. The Vallecitos fault has a nearly continuous trace that extends from the western edge of the Sierra Juarez 65 kilometers to the west end of the Valle de las Palmas (about 29 kilometers southeast of Tijuana). As noted by Gastil and others (1979) the main trace of the fault is marked by erosional topographic features and there is no evidence that the Vallecitos offsets anything younger than the crystalline basement rocks. An unpublished map by a former Stanford graduate student shows only 3 kilometers of right-lateral separation of a Cretaceous pluton boundary (cited in Gastil and others, 1979).

Calabasas Fault

The Calabasas fault is mapped about 5 kilometers east of the Vallecitos fault zone and trends parallel to it for about 30 kilometers in a northwest-southeast direction. In the Valle de las Palmas area, recent movement may be indicated by small sags and saddles, breaks in uplifted alluvial deposits, and relatively uneroded scarplets (Gastil and others, 1975, 1979).

Tres Hermanos Fault

The Tres Hermanos fault zone is located midway between the San Miguel and Agua Blanca fault zones and essentially parallels the San Miguel fault zone. The trace, approximately 45 kilometers long, begins in the batholithic rocks and dies out east of Ensenada. The fault is indicated by pronounced topographic expression and is apparent on high altitude photos, yet recency of movement and sense of displacement are unknown (Gastil and others, 1979).

Agua Blanca Fault Zone

The Agua Blanca fault zone extends about 129 kilometers across the western two-thirds of the Baja California peninsula. The Santo Tomas fault branches off the western portion of the Agua Blanca fault. These faults are distinctive for their west-northwest trend that is more westerly than the strike-slip faults to the north. The trace of the Agua Blanca fault is indicated by abundant geomorphic evidence (Allen and others, 1960; Hamilton, 1971). Typical features are distinct scarps, offset streams, shutteridges, fault sags and saddles, and fault-controlled valleys. Quaternary fan gravels in the Valle de Agua Blanca are offset about 4.8 kilometers in a right-lateral sense; between 11.3 kilometers and 22.6 kilometers of similar separation may be indicated by discontinuous igneous contacts across the fault trace (Allen and others, 1960).

Detailed field mapping (Allen and others, 1960; Gastil and others, 1975) indicates that the east end of the Agua Blanca fault dies out in the Sierra San Pedro Martir and does not intersect the dip-slip faults of the eastern escarpment.

The offshore extension of the Agua Blanca fault west of the landward traces of the Agua Blanca and Santo Tomas faults is characterized by complex submarine topography (Krause, 1965). Recent investigations show that the offshore-onshore fault relationship is not present as a continuous through-going feature. Legg and Kennedy (1979) recognized the offshore portion of the Agua Blanca fault as a series of subparallel en-echelon segments. A component of vertical movement is indicated locally by Quaternary sea floor scarps with several hundred meters of relief (Krause, 1965; Legg and Kennedy, 1979). Near the Todos Santos Islands northwest of Punta Banda, the fault zone makes a northwest bend and continues north in the form of relatively short en-echelon segments trending toward either the San Clemente or the Coronado Banks fault zones. A more detailed and complete discussion of the offshore borderland faults is presented in appendix 2.5P.

Tectonic Implications

Evidence for the amount of total displacement on faults within the San Miguel and Vallecitos fault zones is limited. The suggested amount of lateral offset, where indicated, is poorly defined and ranges from 100 meters to 3 kilometers. North of the Agua Blanca fault zone, the region west of the Sierra Juarez and Sierra San Pedro Martir escarpment has acted as a relatively stable block as indicated by the small amount of overall displacement on the San Miguel fault zone and the Vallecitos fault zone. These two zones are inferred to be relatively young features that, along with similar right-lateral strike-slip faults of the region reflect a change in the relative plate motions from subduction to transform motion along the southern California-Baja California continental margin (Crouch, 1979).

The Agua Blanca fault is an older tectonic element initiated in the late Cretaceous. The east end of the Agua Blanca dies out in the batholithic rocks before reaching the coastal plain of the Gulf. Seismic profiling along the western Gulf margin has shown that the structural elements of the northern Gulf are not continuous with the onshore fault zones in the northern peninsula (Henyey and Bischoff, 1973).

Although some secondary northeast trending faults with scarce indications of left-lateral motion have been mapped in the region, the evidence is generally poor to support the hypothesis of a conjugate fault system. The northwest-trending strike-slip fault systems of the northwestern Baja region appear to be reacting to regional shear influenced by the relative plate motions and are not directly connected with transform features in the Gulf of California.

APPENDIX 2.5J

Possible Connection Between the Rose Canyon and the San Miguel or Vallecitos Fault Zones

Several authors have suggested that an en-echelon relationship may exist regionally between the Rose Canyon fault zone and the San Miguel and Vallecitos fault zones (see section 2.5K.2 for summary and discussion). A possible northwest extension of the presently mapped limits of either the Calabasas or Vallecitos faults has been inferred by these authors largely on the basis of the regional alignment of discontinuous topographic, structural, and geothermal features in the southern San Diego and southeast Tijuana area. However, geologic maps by Kennedy (1975) and Gastil and others (1975) indicate a 55-kilometer distance between the south end of the Rose Canyon fault and the north end of the Vallecitos fault.

Gastil and others (1979) suggest the possibility of a northwest-trending lineament that would continue from the northwesternmost mapped trace of either the Vallecitos or the Calabasas faults, through eastern Tijuana, and across the U.S.-Mexico Border just west of San Ysidro. This suggested lineament crosses an area with a historically quiet seismic record (with the exception of the 1978 Canon de la Presa earthquake).

Features (Gastil and others, 1979) that suggest this lineament are:

A. The subparallel alignment of the Tijuana River Valley and the Valle de las Palmas, trends of faults in the San Ysidro area, and the alignment of several thermal wells

B. The contrast between Eocene stratigraphy north and south of the lineament

C. The mapped traces of northeast-trending dip-slip faults in the southern Tijuana-Rosarito Beach area which do not continue across the lineament

If the lineament suggested by Gastil and others (1979) is a fault, it would trend northwest from the Valle de las Palmas area, cross the Eocene bedrock exposures, continue beneath the deeply alluviated Tijuana River Valley and possibly into the San Diego Bay area (see appendix 2.5K.1 for a discussion of faulting in the San Diego Bay area).

Although this lineament has been suggested by Gastil and others (1979), the lack of faulting in the well-exposed Eocene bedrock and the lack of fault features recognized on aerial photographs of the area by Gastil suggest that no significant faulting has occurred in this area since Eocene time. Geophysical data by Kennedy (1977) (see table 2.5K-1, in appendix 2.5K) does not identify significant faulting along the proposed connection of the San Miguel and Vallecitos faults and the Rose Canyon fault in the area south of San Diego Bay and north of the International Border. Therefore, the applicant's position is that the observed evidence is not supportive of a through-going fault that could connect the Rose Canyon Fault Zone (RCFZ) with either the Vallecitos or San Miguel fault zones.

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The most prominent faulting associated with the southern part of the RCFZ is to the southwest, rather than to the southeast. The south part of the RCFZ is represented by a widening zone of shorter, principally dip-slip faults that are mapped in the offshore area west of San Diego Bay. These faults generally diminish in expression and die out when traced in a southerly direction. This portion of the RCFZ is discussed in detail in section 2.5K.1.

2.5J.3 SEISMICITY OF NORTHERN BAJA CALIFORNIA

Northern Baja California is an area of extremely high seismicity; at least 13 earthquakes of magnitudes greater than 6.0 have occurred since 1900 (Brune and others, 1979). Previous epicenters in this region (Hileman and others, 1973; FSAR figure 2.5-20) appear to scatter across the peninsula, suggesting a broad zone of deformation. Recent investigations, including field studies (Reyes, et al., 1975; Johnson; et al., 1976) and the relocation of epicenters (Leeds, 1979; Brune and others, 1979) in the region, indicate that the vast majority of earthquakes are associated with a few active faults.

The San Miguel Fault appears to be the seismically dominant fault in the northern Baja California region. In 1956, four large earthquakes (magnitude 6.1 to 6.8) occurred along the San Miguel fault near the town of San Miguel (Brune and other, 1979). In addition, Leeds (1979) has relocated five earthquake epicenters with magnitudes greater than 5.0 to the San Miguel fault zone; one of these was relocated near the northwest end of the San Miguel fault near the Vallecitos fault. Relocation errors as large as 90 kilometers were noted in earlier catalog locations.

Micro-earthquake activity in the San Miguel fault zone is very high. Reyes and others (1975) operated high-gain portable seismographs at 22 stations in this region with detection level estimated to be less than magnitude 2. Sixteen of these stations reported micro-earthquake rates greater than 27 events per day. The highest rates, exceeding 100 events per day, were recorded near the southeast end of the San Miguel fault. In a study by Johnson and others (1976), and San Miguel fault was found to be seismically active along its length and responsible for the vast majority of recorded earthquakes in this region. Hypocenters on the San Miguel fault ranged in depths from 0 to 20 kilometers. Composite focal mechanisms from this study indicated a mixture of right-lateral and dip-slip (east side up) movement that was consistent with surface evidence.

No large historic earthquakes are positively correlated with the Agua Blanca fault (Allen and others, 1960; Brune and others, 1979). Magnitude 6.0 and 6.3 earthquakes of 1954, previously located along this fault, have been relocated to the San Miguel fault (Leeds, 1979). Very low rates of micro-earthquake activity have been recorded on the Agua Blanca fault (Johnson and others, 1976).

The activity of the plate boundary to the east of the hypothesized OZD is compared with parallel faults in the June 1979 report and a westward decrease in activity is noted. It is clarified in appendix 2.5P that areas to the west of the hypothesized OZD do not necessarily maintain that westward decrease in seismicity. In Baja California, the basis for evaluating comparative levels of activity is limited by data availability; however, the seimic activity in Baja during the period 1971 to the present does provide a limited basis for such an evaluation.

In considering all the earthquakes with M_L of 6.0 or greater north of 31.5° latitude, most seismic slip appears to be associated with either the San Miguel fault or with the ridge-transform fault system extending from the Gulf of California to the Salton Sea. These earthquakes are listed in table 2.5J-1 and are taken from Brune and others (1979), Hileman and others (1973), and Caltech (unpublished). The relationship of Thatcher and Hanks (1973) can be used to calculate moment values for these earthquakes. Although the relationship proposed by Thatcher and Hanks was developed for M_s, the use of M_L values will not produce a significant discrepancy and is suitable for comparative purposes. The cumulative moment thus calculated for the San Miguel zone is 2.9×10^{26} dyne-cm and for the plate boundary zone is 12.4×10^{26} dyne-cm. Assuming that the fault zones are of similar depth, the total seismic slip is directly proportional to the moment and varies inversely as the fault lengthens. Since the plate boundary zone is about twice as long as the San Miguel fault zone, the total slip on the plate boundary is about twice the total slip on the San Miguel. Thus, for the Baja California area, there is a decrease in historical seismicity to the west of the plate boundary faults, but the westward activity is dominated by the San Miguel fault.

Various authors have alternately proposed and contested that the hypothesized OZD, Newport-Inglewood Zone of Deformation (NIZD), RCZD, and San Miguel fault zones are connected (Abbott and Elliott, 1979). At the present time "exact relationships between these fault zones have not been established" Brune and others, 1979). Based on data presently available (Abbott and Elliott, 1979; Hileman and others, 1979; Reyes and others, 1979), large or small earthquakes or micro-earthquakes do not delineate such a connection. A very small number of small earthquakes have occurred in the San Diego and Tijuana regions and near the hypothesized OZD; however, the pattern is highly diffuse (Hileman and others, 1979). The only tentative pattern in the seismicity is a short EW trend at San Diego which may intersect a weak NW-SE trending zone of activity near the Coronado Banks fault zone (Legg and Kennedy, 1979). This can only be seen in the more accurately located epicenters. One earthquake (M_L = 3.5, Brune and others, 1979; M_L = 4.1, Caltech) has been well located between Tijuana and the mapped trace of the San Miguel fault zone. This event does not constitute evidence of a connection between the San Miguel and Rose Canyon, since events of this size commonly occur in many areas of southern California and Mexico with no proximity to through-going faults (Hileman and others, 1979). An example of a well located event of this kind in Mexico is the Pino Solo earthquake (M = 5.0) of 1974 (Brune and others, 1979).

Table 2.5J-1

EARTHQUAKES OF MAGNITUDE 6.0 AND GREATER
ALONG PLATE BOUNDARY AND IN NORTHERN BAJA

Date	Magnitude	Fault
11-21-15	7.1	Cerro Prieto
12-30-34	6.5	Laguna Salada
12-31-34	7.1	Cerro Prieto
2-24-35	6.0	San Miguel
5-19-40	6.7	Imperial
12-07-40	6.0	Cerro Prieto
10-24-54	6.0	San Miguel
11-12-54	6.3	San Miguel
2-09-56	6.8	San Miguel
2-09-56	6.1	San Miguel
2-14-56	6.3	San Miguel
2-15-56	6.4	San Miguel
8-07-65	6.3	Cerro Prieto
4-09-68	6.5	Borrego
10-15-79	6.6	Imperial

In summary: (1) The historical seismicity of the northern Baja California area is dominated by the high level of activity of the San Miguel fault, although this level is about one-half as high as that on the plate boundary faults (Cerro Prieto, Imperial, and others) to the east, (2) Based on seismological evidence, the San Miguel fault does not appear to be mechanically connected to the hypothesized OZD to the north.

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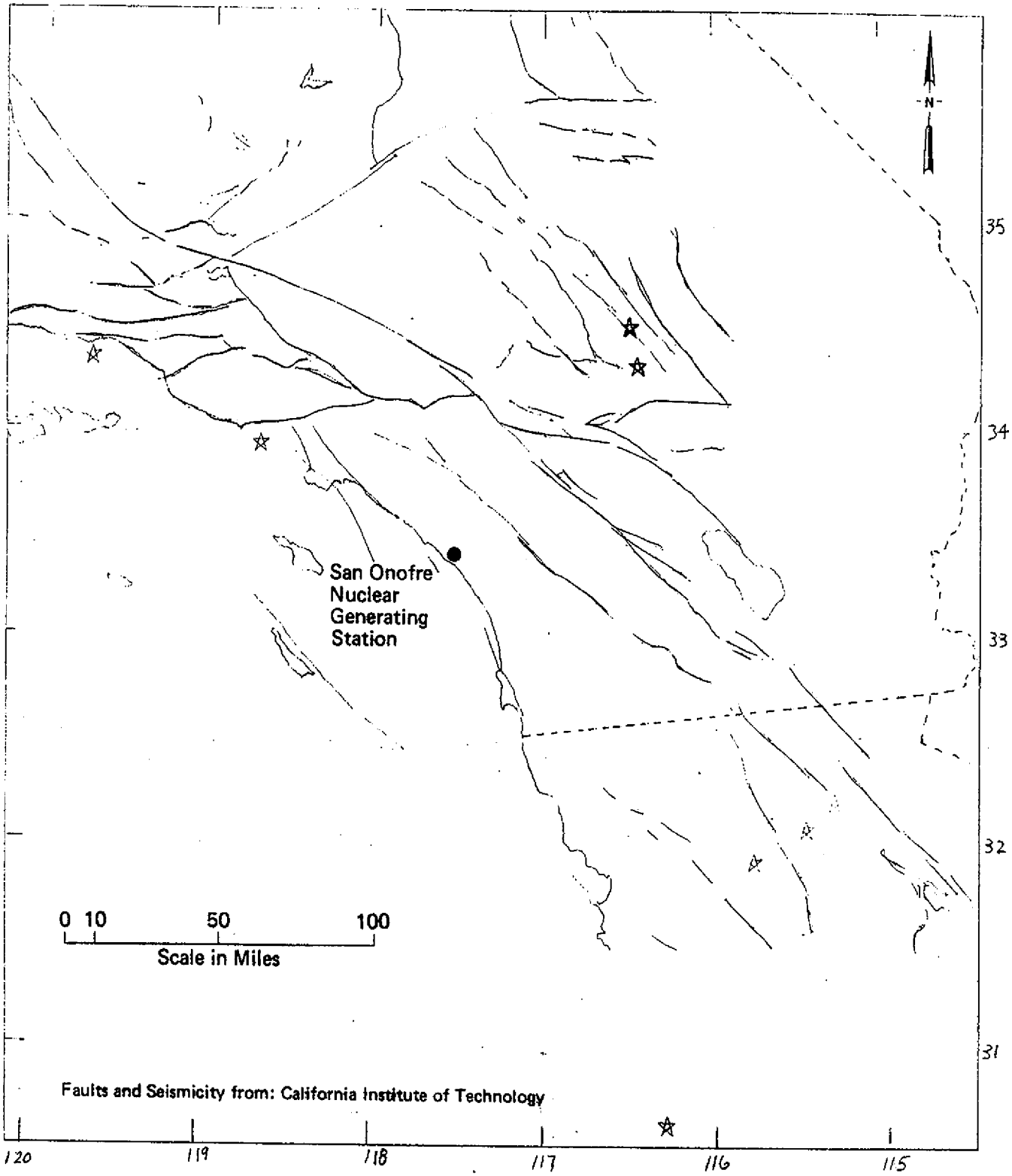
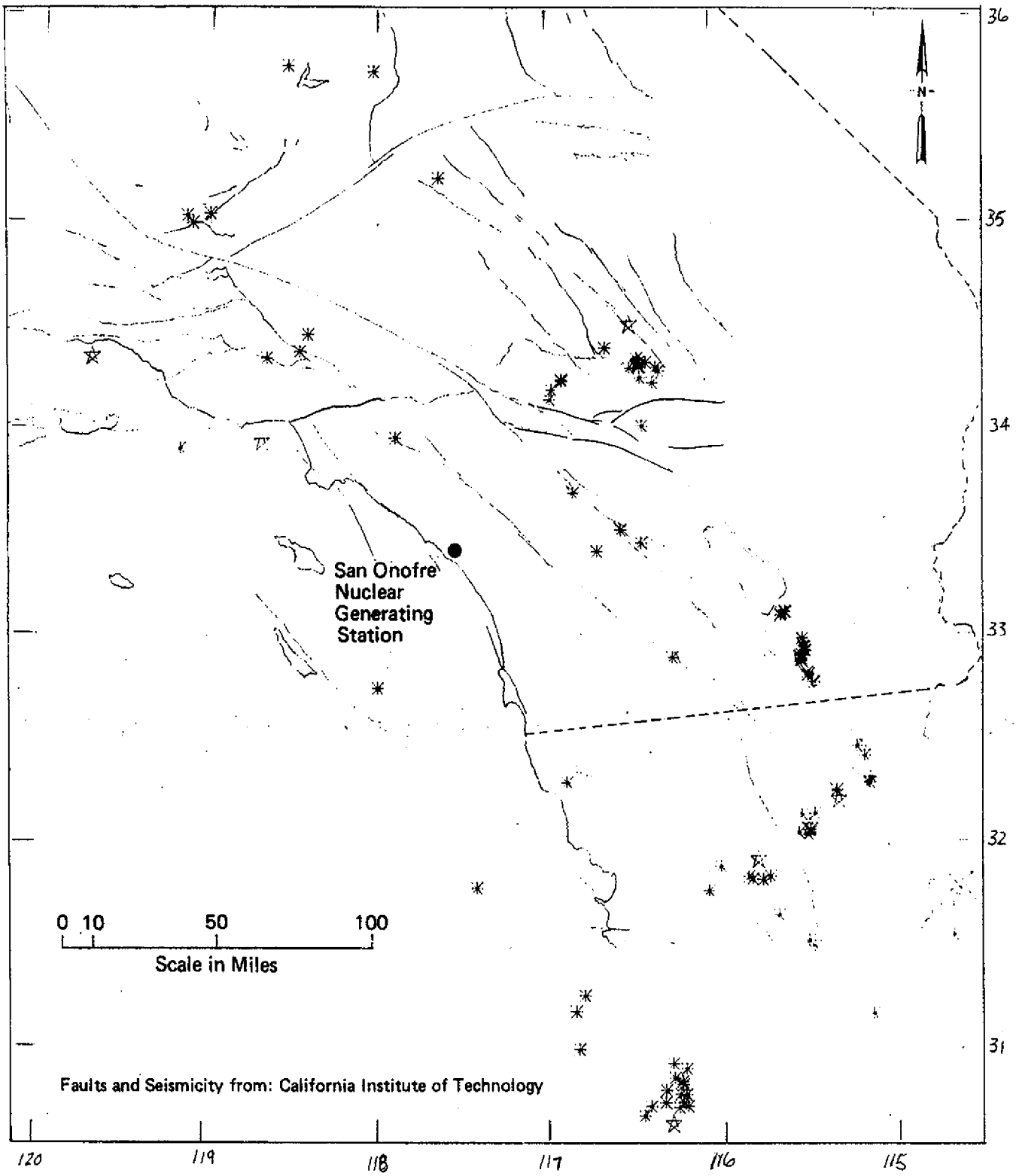


Updated

SAN ONOFRE
NUCLEAR GENERATING STATION
Units 2 & 3

SEISMICITY WITHIN 200 MILES OF THE SAN ONOFRE SITE JANUARY 1975 THROUGH SEPTEMBER 1979, $M_L \geq 5$

Figure 2.5J-1



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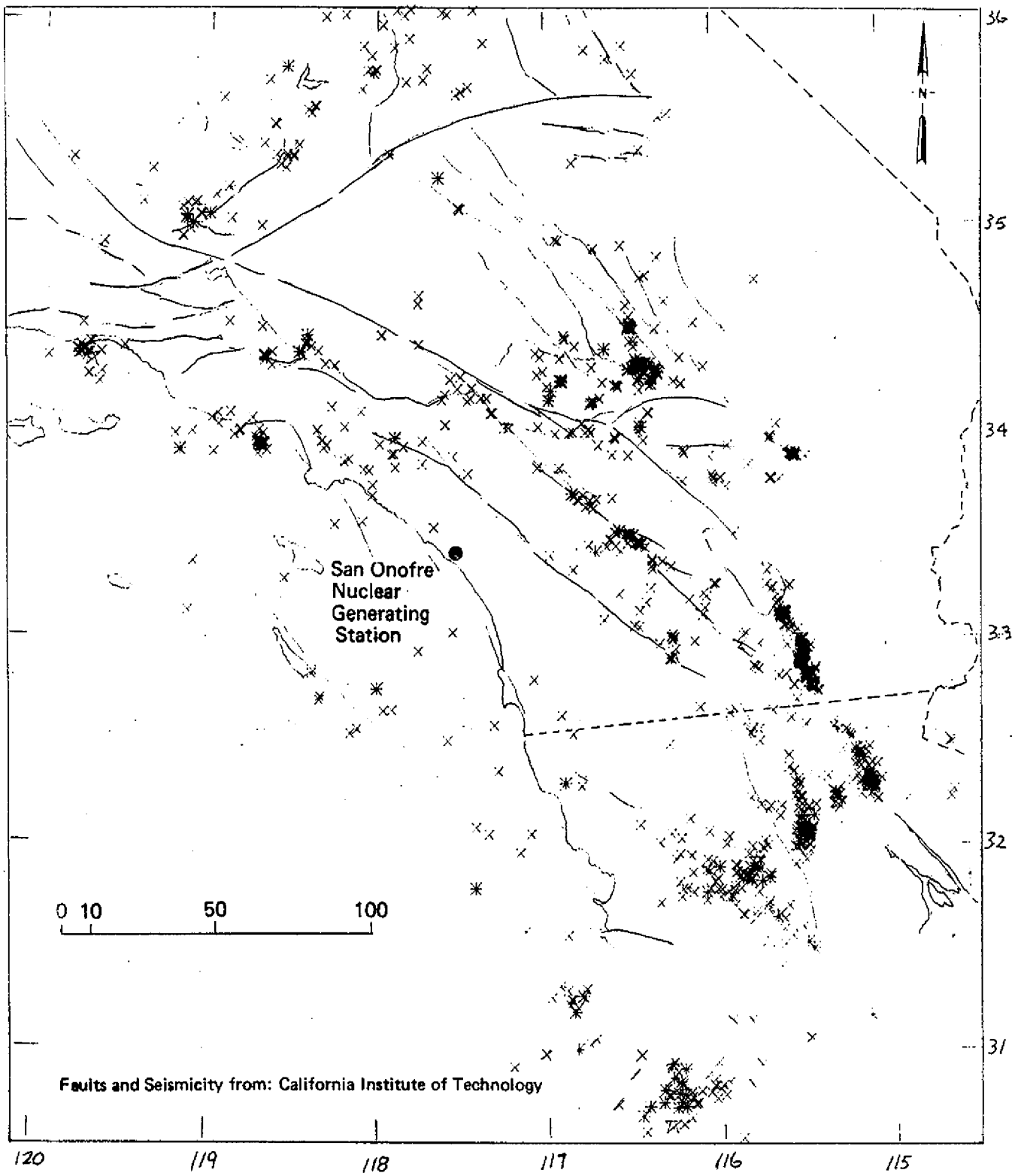
SAN ONOFRE
NUCLEAR GENERATING STATION
Units 2 & 3

SEISMICITY WITHIN 200 MILES OF THE SAN ONOFRE SITE JANUARY 1975 THROUGH SEPTEMBER 1979, $M_L \geq 4$

Figure 2.5J-2



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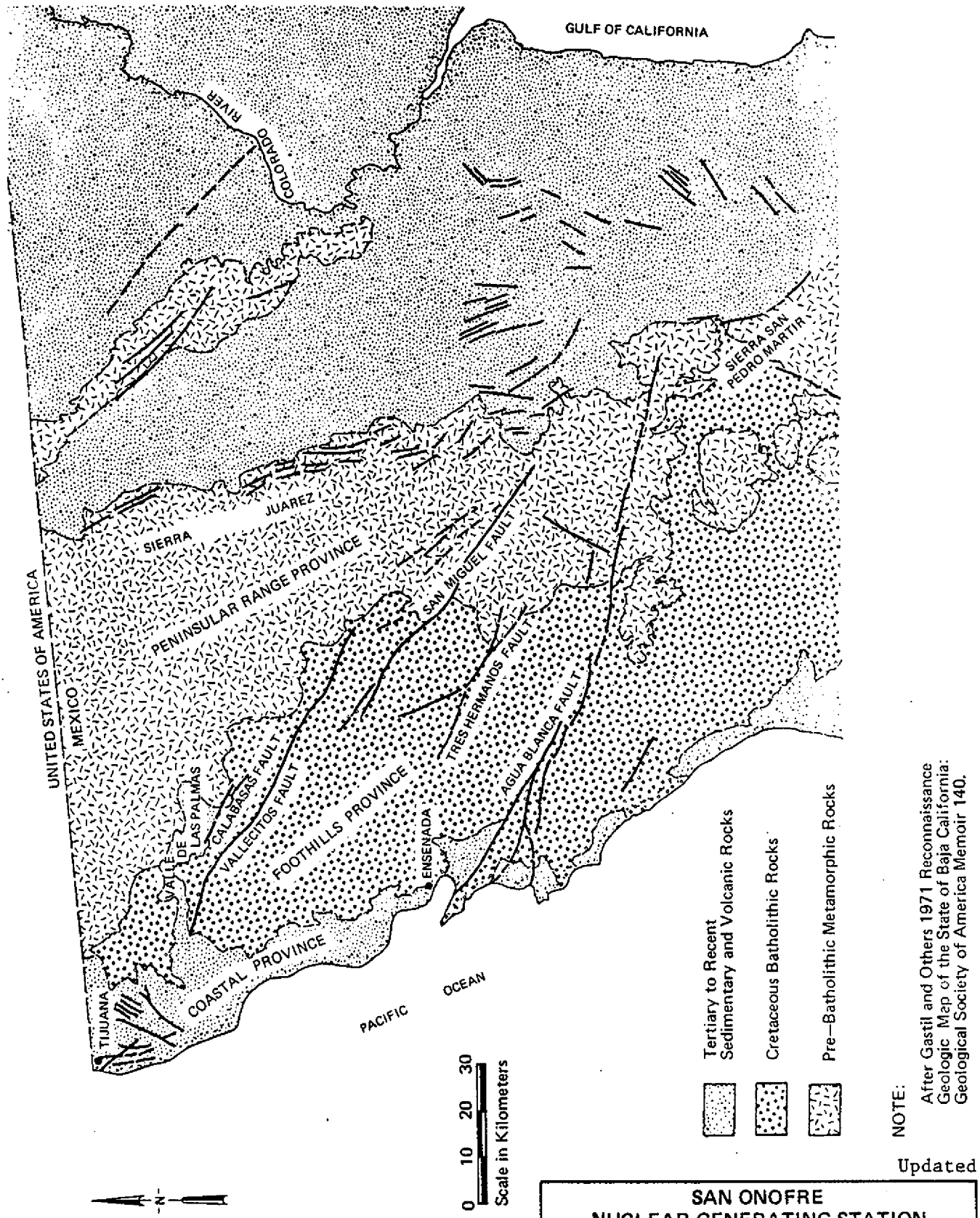
SAN ONOFRE
NUCLEAR GENERATING STATION
Units 2 & 3

SEISMICITY WITHIN 200 MILES OF THE SAN ONOFRE SITE JANUARY 1975 THROUGH SEPTEMBER 1979, $M_L \geq 3$

Figure 2.5J-3



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SAN ONOFRE NUCLEAR GENERATING STATION
Units 2 & 3

GENERALIZED MAP OF NORTHERN BAJA CALIFORNIA PHYSIOGRAPHIC PROVINCES AND DISTINCT GEOLOGIC TERRANE

Figure 2.5J-4

APPENDIX 2.5K

EXTENT OF ROSE CANYON FAULT ZONE

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APPENDIX 2.5K

EXTENT OF ROSE CANYON FAULT ZONE

2.5K.1 BASIS FOR ASSUMPTION THAT THE ROSE CANYON FAULT ZONE DIES OUT TOWARD THE SOUTH IN THE VICINITY OF SAN DIEGO

The Rose Canyon fault zone (RCFZ) has been studied offshore, north of Point La Jolla, and southwest of the San Diego Bay (Moore, 1972; Moore and Kennedy, 1975). Faults mapped in these areas have been located on the basis of generally wide-spaced acoustic profiles and inferred correlation with bathymetric relief (for further discussion see section 2.5K.2). More detailed acoustic profile surveys by Kennedy (1979) and by Kennedy and others (1977 and 1978) in these offshore areas have refined the location and current understanding of this portion of the Rose Canyon fault zone. The specific information developed by Kennedy and others is summarized in table 2.5.K-1.

The RCFZ in the San Diego area is characterized in general by a series of structural and topographic highs and lows that include (from north to south): the offshore faults of the Point La Jolla area (low), the Mt. Soledad area (high), Mission Bay (low), Morena-Old Town area faults (high), and the San Diego Bay area (low). The southernmost of these alternating features is underlain by the San Diego Basin that is roughly defined by the down-to-the-west faults of the La Nacion system (Artim and Pinkney, 1973) and the down-to-the-east faults offshore from San Diego Bay (Kennedy and others, 1977). This structural low, or graben, implies that the southern portion of the RCFZ is characterized by a widened zone of extensional, rather than compressional style faults, and further suggests that the sense of displacement on this portion of the RCFZ is dip-slip rather than strike-slip.

Faulting along the RCFZ in the area south of the Morena-Old Town is not well defined. Onshore evidence of fault displacement is sketchy. (For further discussion, see appendix 2.5N, section 2.5N.11. The bulk of evidence for faulting at the south end of the RCFZ consists of faults identified by acoustic profiling in San Diego Bay and offshore of San Diego (Moore and Kennedy, 1975 and Kennedy and others 1977). Faults identified offshore are more prominent than the faults in the southern end of San Diego Bay. The offshore faults are also expressed as fault scarps where they come onshore at Coronado (Kennedy and others, 1977). This evidence strongly suggests that a southern extension of the RCFZ is associated with the faulting and extends offshore of San Diego and not to the south through San Diego Bay.

In summary, the character of the faulting within the RCFZ changes in the southern part of San Diego and becomes a wide zone of faulting characterized primarily by a dip-slip component. The prominent faults extend offshore to the southwest. Current data indicates that the faulting within this wide zone dies out to the south and does not connect to the Calabasas fault or the Vallecitos fault zone.

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Table 2.5K-1
SUMMARY RCFZ INFORMATION, KENNEDY (1979)
AND KENNEDY AND OTHERS (1977, 1978)
(Sheet 1)

Area Investigated	Summary of Data
RCFZ off Point La Jolla	Kennedy and others (1978) mapped a widening zone of west to northwest-trending faults offshore to the north and west of the mapped faults of the RCFZ onshore near Mt. Soledad. The more westerly-trending faults of this zone were inferred to be principally dip-slip and generally to define a structural low underlying the La Jolla submarine canyon. Stratigraphic separations on the youngest faulted sediment (late Pleistocene to Holocene) of these dip-slip faults were on the order of 9 to 18 meters. Further west, a subzone of north-northwest trending faults was mapped oblique to the trend of the La Jolla canyon. These canyon. These faults were generally discontinuous and appeared to be overlain by about 5 meters of unfaulted Quaternary sediment. The eastern edge of Kennedy and others offshore zone parallels the coast line to the 33 N latitude which is the limit of profiling. Along the eastern edge, acoustically transparent (late Pleistocene and Holocene) sediment was not faulted although near surface disruption of the Quaternary horizon was indicated. The discontinuous en-echelon pattern of the eastern edge of this offshore zone is similar to that seen within the RCFZ at San Diego Bay.
RCFZ off San Diego Bay	Detailed acoustic profiling by Kennedy and others (1977) in the offshore region west of and including San Diego Bay indicated subzones of northeast to northwest-trending down-to-the-east faults. Three of the longer faults (from north to south: the Spanish Bight fault, Coronado fault, and the Silver Strand fault) were seen to have a prominent central portion (locally expressed onshore in the North Island-Corondo vicinity) that gradually died out when traced toward the north or south. No surface displacements were identified in these offshore faults, although displacement locally extends to within 5 to 10 meters of the sea floor. When traced in a southerly direction, these faults generally become less persistent and appear to die out in short en-echelon splays. The most southerly fault, the Silver Strand fault, can be traced to the vicinity of the International Border where it also becomes less persistent and dies out in several en-echelon branches.

Table 2.5K-1
SUMMARY RCFZ INFORMATION, KENNEDY (1979)
AND KENNEDY AND OTHERS (1977, 1978)
(Sheet 2 of 2)

Area Investigated	Summary of Data
RCFZ in San Diego Bay	Kennedy and others (1977) also describe a series of relatively short (<3 kilometers long) discontinuous faults east of the Silver Strand fault in the southern San Diego Bay area. Some of these faults appear prominent on acoustic profiles, but all are short and none displace the bay floor. Some of these faults extend to within to within 5 to 10 meters of the bay floor.
RCFZ south of San Diego Bay	Kennedy and others (1977) conducted gravity, ground magnetic, and refraction surveys to determine if a proposed trace of the RCFZ crossed the Otay Valley area, south of the San Diego Bay, and continued south across the International Border toward the San Miguel-Vallecitos fault zone SMVFZ (see appendix 2.5J for further discussion). Gravity and magnetic profiles indicated several anomalies that could be associated with faults of the La Nacion system, but they are located east of a projected RCFZ-SMVFZ alignment. However, no significant anomalies were recognized on profiles across southeast projections of presently mapped faults in the RCFZ. The refraction data collected in this survey were limited by logistic and electronic difficulties. As a result, it was not possible to determine unequivocally if the section was faulted (Kennedy and others, 1977).

2.5K.2 SUMMARY OF EVIDENCE FOR EXTENSION OF THE RCFZ AND REBUTTAL TO THAT EVIDENCE

The works which support the argument that the RCFZ extends northward to connect with the SCOZD and/or southward into Mexico will be discussed in chronological order (i.e., (A. Corey, 1954; B. Emery, 1960; C. King, 1969; D. Wiegand, 1970; E. Moore, 1972; F. Moore and Kennedy, 1975). Each of these discussions will be followed by a brief rebuttal.

A. Corey (1954) compiled paleogeographic and paleostructural maps of southern California and the adjacent continental borderland area to interpret the Tertiary history of the region. On his "pre-Pliocene fault trend" map, he inferred that several offshore faults extend from the Palos Verdes peninsula south, roughly parallel to the present coastline, to the onshore RCFZ area, then continue south in the offshore area west of Baja California.

Corey's report deals only with Tertiary sedimentary history on a regional scale and does not deal with the detailed geology of any one area. He depicted the Rose Canyon fault as being right-lateral with schist basement to the west and granitic basement to the east. Exploratory borings have subsequently shown that the Santiago Peak Volcanics form the basement on both sides of the Rose Canyon fault (Gray and others, 1971). This and the presence of the same Cretaceous and Eocene formations on opposite sides of the fault indicate the Rose Canyon fault has little displacement along it; therefore, Corey's interpretation is incorrect.

B. Emery (1960) prepared a fault map of the sea floor off southern California depicting a long "primary fault" trend similar to Corey's but along the base of the slope west of the OZD that continued on offshore and west of Baja California.

Emery, however, notes that the faults are located primarily on the basis of submarine topography. Emery assumes that such topography is for the most part of structural origin. Age determination of these structural scarps is equivocal as "some scarps on the sea floor that are believed to be late Miocene age appear sharp and clear from sounding data" (Emery, p 77). Thus, although Emery identified a topographic lineament roughly parallel but west of the OZD, its location lies further offshore at the base of the topographic scarp and its true character and age are undocumented.

C. King (1969), in a publication of the tectonic history of North America, described the regional tectonic setting of California and Baja California and discussed the existence of prominent high angle, northwest-trending right-lateral faults. He dealt specifically with the San Andreas fault in California and its relationship to the opening of the Gulf of California. No specific reference was made to the faulting offshore of southern California.

D. Wiegand (1970) postulated that a fault underlying San Diego Bay was an extension of the Rose Canyon fault that "may be a segment of a longer fault system which includes ... the San Miguel Fault in Baja California." This extended fault zone was inferred largely on the basis of the alignment of discontinuous topographic, structural, and geothermal features in the San Diego Bay-Tijuana region.

The geothermal wells used by Wiegand to support a fault in the south San Diego Bay area do not align with his proposed fault. The topographic depressions in the bay floor, used to support a proposed fault alignment, are underlain by "slump sand" of different character from the surrounding sediments, according to Wiegand (p 112). It seems quite likely that these are disrupted sediments resulting from liquefaction rather than a sag pond depression. This area could also be a drainage channel preserved on the bay floor from a lower stand of sea level.

Weigand notes faults which are transverse to the proposed fault alignment in San Diego Bay. He suggests that the general quiescence of the Rose Canyon fault zone may be the result of these transverse faults locking off the northwest-southeast trend. It is also noteworthy that Kennedy and others (1977) surveys of the South Bay area did not identify anomalies suggestive of a southward extension of a fault through this area, but rather of a south-southwesterly trend into the offshore area west of San Diego Bay.

E. Moore (1972) proposed an offshore extension of the Rose Canyon fault north of Point La Jolla based on generally wide spaced acoustic profiles. He acknowledged that the location of the Rose Canyon Fault "is less certain to the southeast beyond San Diego Bay" and only suggested that the Rose Canyon fault might follow the Tijuana River Valley to connect further south with the San Miguel fault. A review of the data in the border area, as discussed in appendix 2.5J, indicates that this proposed connection is incorrect.

F. Moore and Kennedy (1975) mapped several faults within and to the southwest of San Diego Bay on the basis of acoustic reflection profiles. The indicated fault pattern suggested that the Rose Canyon fault zone broadens and becomes en-echelon at the San Diego Bay area, roughly defining the west side of a structural low. This portion of the zone is characterized by normal down-to-the-east faulting. Their survey found the strongest evidence of faults extending southwestward across the north San Diego Bay area and offshore to the southwest, rather than to the southeast. Their survey also identified diminishing evidence of faulting to the southwest suggesting that the RCFZ dies out in this direction near the international border. It is the Applicant's position that this interpretation represents the most probable projection of the RCFZ into the offshore area and that it further supports the lack of continuity with the Vallecitos or San Miguel fault zones.

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