INTERPRETIVE RESULTS
HIGH RESOLUTION GEOPHYSICAL SURVEY
IN SELECTED AREAS
BETWEEN
DANA POINT AND OCEANSIDE,
OFFSHORE CALIFORNIA

Prepared for:
SOUTHERN CALIFORNIA EDISON COMPANY
Rosemead, CA

By:
NEKTON, INC.
San Diego, CA

July 28, 1980

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I. INTRODUCTION

The survey discussed in this report was conducted for Southern California Edison Company to supplement the large body of surveys already conducted in the vicinity of San Onofre Nuclear Generating Station. The areas covered by the survey are identified in Exhibit I. The two survey areas southeast of the site were selected to determine whether or not the Cristianitos Fault projects toward the Offshore Zone of Deformation (O.Z.D.). The survey area northwest of the site was selected to determine the existence or lack thereof of faulting parallel to the coast north of the site.

II. OBJECTIVES OF THE SURVEY

The primary objectives of the survey were as follows:

a) To identify, if possible, the seaward extension of the Cristianitos Fault, which is mapped onshore 0.8 kilometres (0.5 miles) southeast of the San Onofre Nuclear Generating Station (see Exhibit II).

b) To determine if the Cristianitos Fault connects with the O.Z.D.

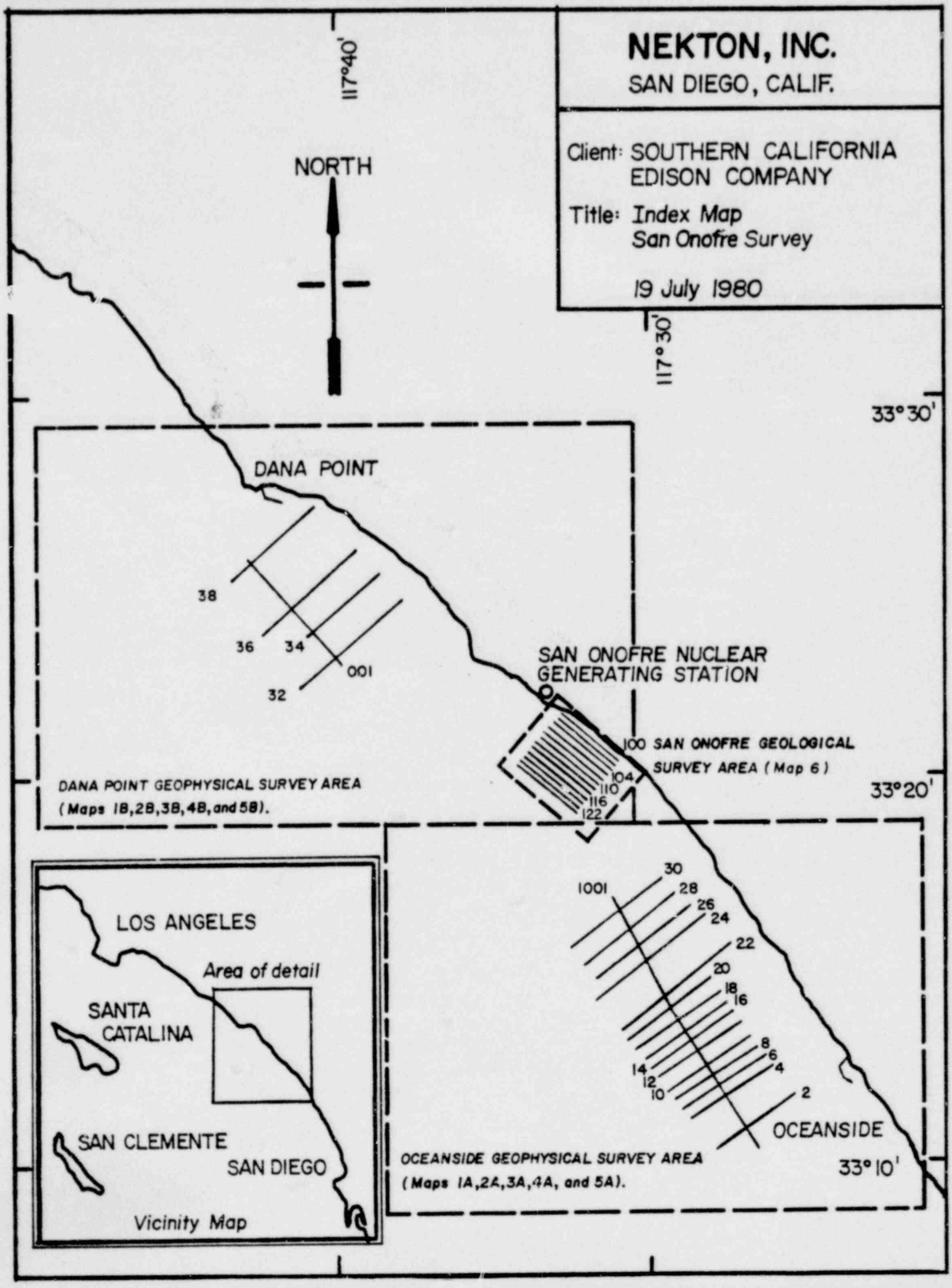
c) To identify and map other faults and folds within the areas surveyed.

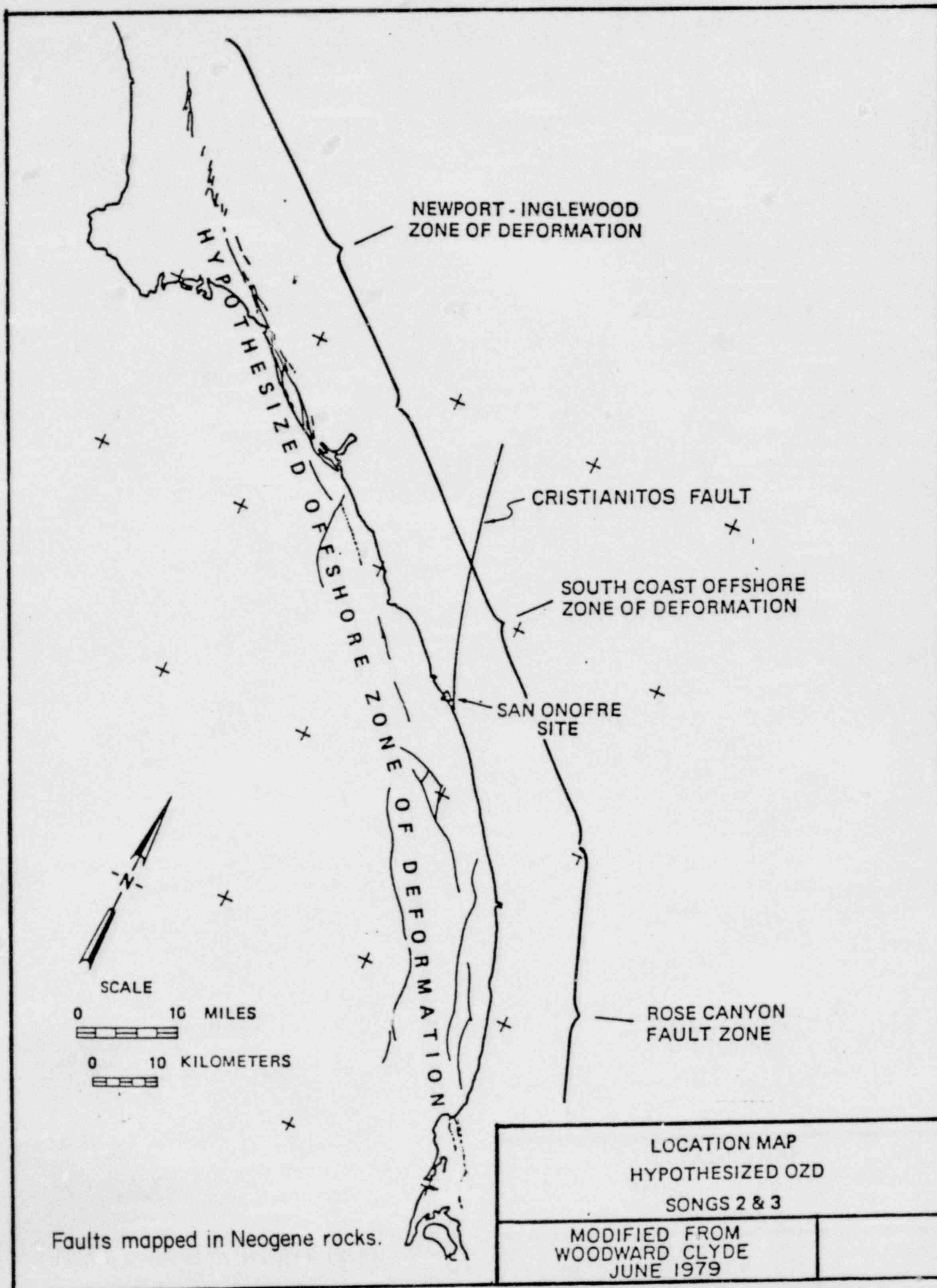
d) To determine whether any faults show evidence of Holocene movement.

III. CONCLUSIONS

Based upon data gathered we offer the following conclusions:

a) The Cristianitos Fault does not project far enough seaward (i.e., south-southeasterly) to be identified in the Oceanside survey area (see Exhibit I). Where the fault may be projected to occur, there is no evidence of its existence. We conclude that along its offshore projection, displacement diminishes and the Cristianitos Fault dies out, possibly in a number of lesser faults and small folds. It does not connect to the O.Z.D.


NEKTON, INC.
SAN DIEGO, CALIF.
Client: SOUTHERN CALIFORNIA EDISON COMPANY
Title: Index Map San Onofre Survey
19 July 1980
117°40'
117°30'
NORTH
33°30'
33°20'
33°10'
DANA POINT
38
36
34
32
001
SAN ONOFRE NUCLEAR GENERATING STATION
100 SAN ONOFRE GEOLOGICAL SURVEY AREA (Map 6)
104
110
116
122
DANA POINT GEOPHYSICAL SURVEY AREA
(Maps 1B,2B,3B,4B, and 5B).
1001
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
OCEANSIDE
OCEANSIDE GEOPHYSICAL SURVEY AREA
(Maps 1A,2A,3A,4A, and 5A).
LOS ANGELES
Area of detail
SANTA CATALINA
SAN CLEMENTE
SAN DIEGO
Vicinity Map



LOCATION MAP
HYPOTHESIZED OZD
SONGS 2 & 3

MODIFIED FROM
WOODWARD CLYDE
JUNE 1979

b) The <u>Offshore Zone of Deformation (O.Z.D.)</u> was mapped parallel to the coastline for 8.8 kilometres (5.5 miles) in the central and northern Oceanside survey area (see Exhibit I, lines 10 to 30). In the central part (lines 10 to 22) at least two branches of the fault occur and their width is limited. To the north it broadens to a zone of deformation up to 0.6 kilometres (0.4 miles) wide. The O.Z.D. is not present in the Dana Point survey area.

c) <u>Other faulting offshore</u> -- a number of minor faults are interpreted to be present offshore in both the Oceanside and Dana Point survey areas. Minor faults in the Oceanside area are short in length and occur below a Pleistocene erosion surface in Tertiary age beds. In the Dana Point area the faults are not traceable from line to line.

d) <u>Fault movement</u> -- none of the minor faults shows evidence of movement following the period of erosion which developed the Pleistocene erosion surface. Eighteen kilometres (11 miles) south of San Onofre, the O.Z.D. shows evidence for at least two periods of probable movement. Movements during one period have displaced the Pleistocene erosion surface and the movements during the other period appear (locally) to displace terrace deposits of probable Holocene age.

IV. <u>DISCUSSION OF INTERPRETIVE MAPS</u>

The maps discussed below are found at the back of this report.

A. <u>Shot Point Base Map(s)</u> (Maps 1A and 1B) were prepared by Navigation Services, Inc., Ventura, California. During the survey shot points (i.e., navigational location fixes) were taken at preplotted intervals of 152 metres (500 feet). The final map shows the actual track lines surveyed and shot points recorded for the June 15 and 16 operations. Maps 5A and 5B, the Seafloor and Water Column Anomaly Map(s), show the track lines surveyed on June 6 and 7. Shot points for maps 1 through 5 have been plotted at a scale of 1:24,000 without stepback corrections. The stepback corrections, i.e. differences in location of the profiling systems and the navigation antenna, are as follows: watergun system: 48.5 metres (159 feet); 3.5 kHz subbottom profiling system: 15.0 metres (49 feet); side scan sonar system: variable between 40 and 250 metres (131 and 820 feet) depending on water depth and length of cable deployed.

B. The Structure Map(s) (Maps 2A and 2B) are contoured on the angular unconformity formed by a buried Pleistocene erosion surface. They were constructed from the 3.5 kHz subbottom profiles and the watergun profiles. Contour interval is 10 msec. of two-way travel time measured from sea level to the unconformable surface.

The Pleistocene unconformity is a gentle west-dipping surface separating unconsolidated marine terrace deposits from moderately deformed and truncated Tertiary sedimentary beds. These beds probably belong to the Capistrano, San Mateo, and Monterey Formations of Late Miocene age, and the San Onofre Breccia of Middle Miocene age. In some places, mostly west of the O.Z.D. in the Oceanside survey area, the unconformity is irregular with local relief of up to 10 msec. (8.4 metres or 27 feet) (see Exhibit III). Most of this relief is due to differential Pleistocene erosion of units in the San Onofre Breccia. Locally, however, post-erosion faulting of the unconformity cannot be completely discounted.

In the nothern part of the Oceanside area (lines 24 to 30 on Map 2A), there is generally no vertical offset of the Pleistocene surface associated with the O.Z.D. (see Exhibit IV). The actual location of the zone and even its presence is ill defined. Limits were based on confused reflectors and areas with no reflectors, combined with reasonably well defined crests of anticlines. The zone varies from two to more than four shot points (300 to over 600 metres) in width.

Offshore of Oceanside, along the southern portion of the mapped O.Z.D. (lines 10 to 22 on Map 2A), the surface of the Pleistocene unconformity has local vertical offset of up to 16 msec. (13 metres or 44 feet) (see Exhibit V). This suggests a possible post-erosion surface movement with a vertical component of up to 13 metres (44 feet). However, the difference in elevation may also be explained by differential Pleistocene erosion, in which case, the last movement on the O.Z.D. at these localities could be pre-Pleistocene.

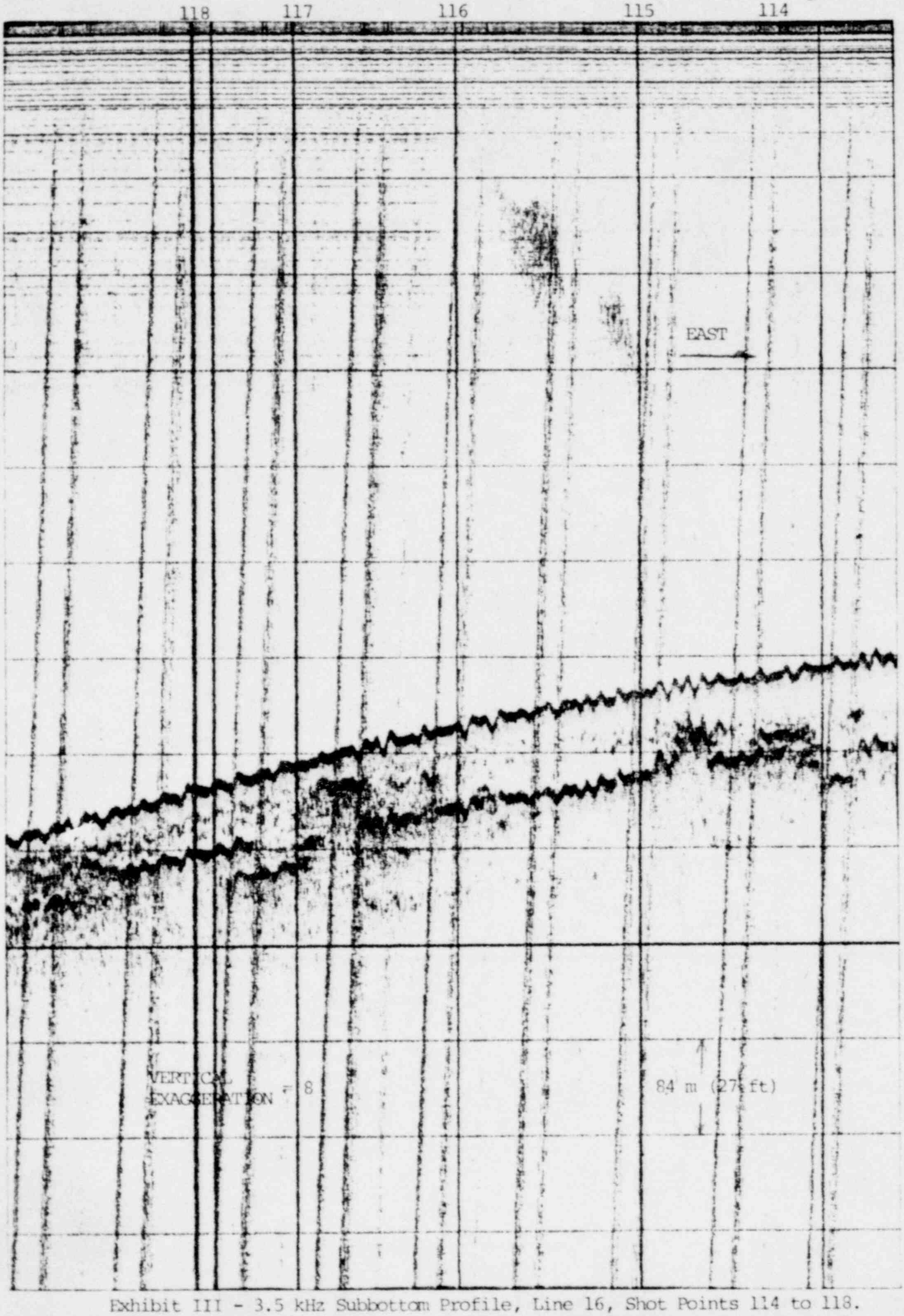


Exhibit III - 3.5 kHz Subbottom Profile, Line 16, Shot Points 114 to 118.

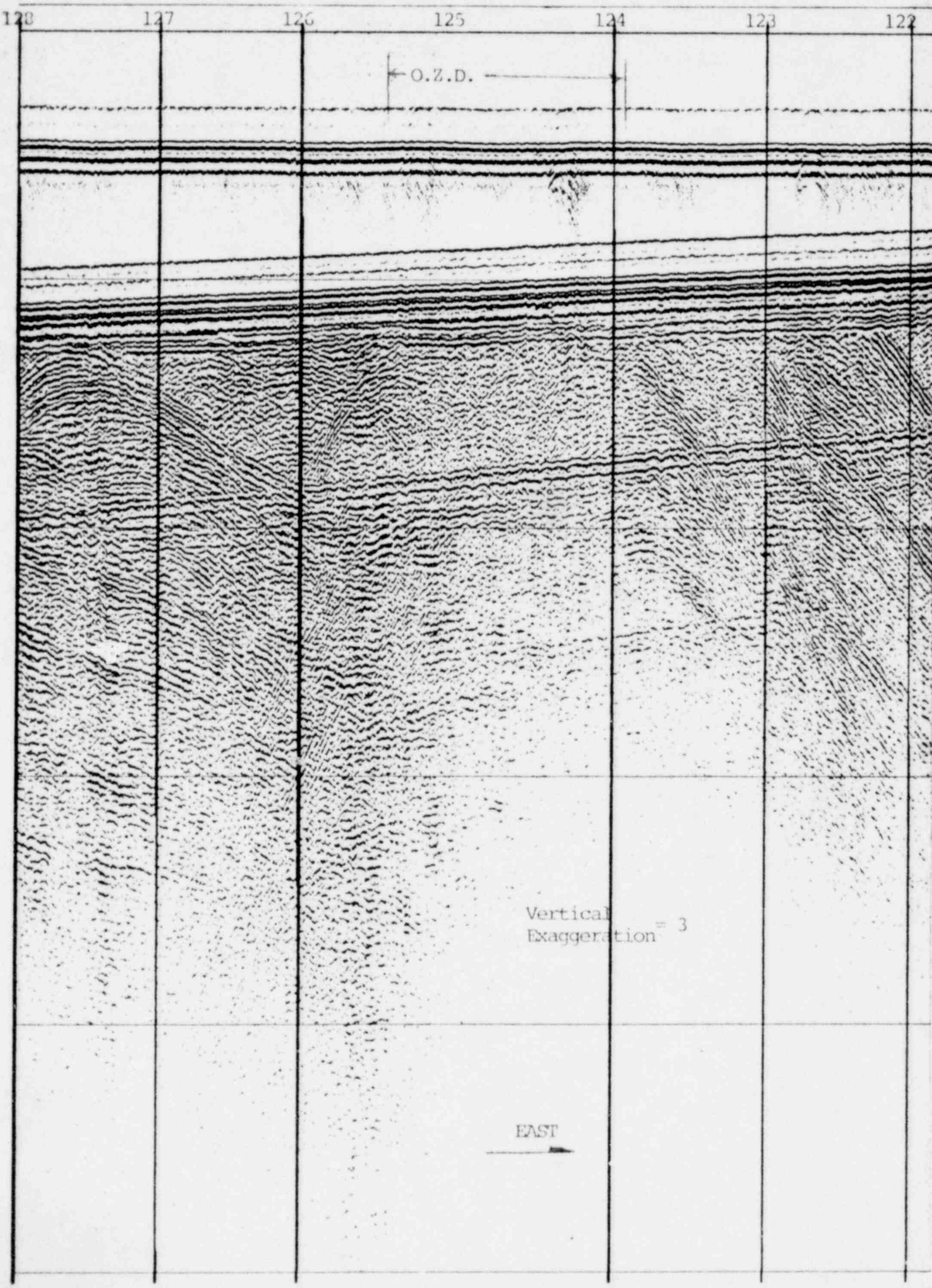


Exhibit IV - Watergun Profile, Line 24, Shot Points 122 to 128.

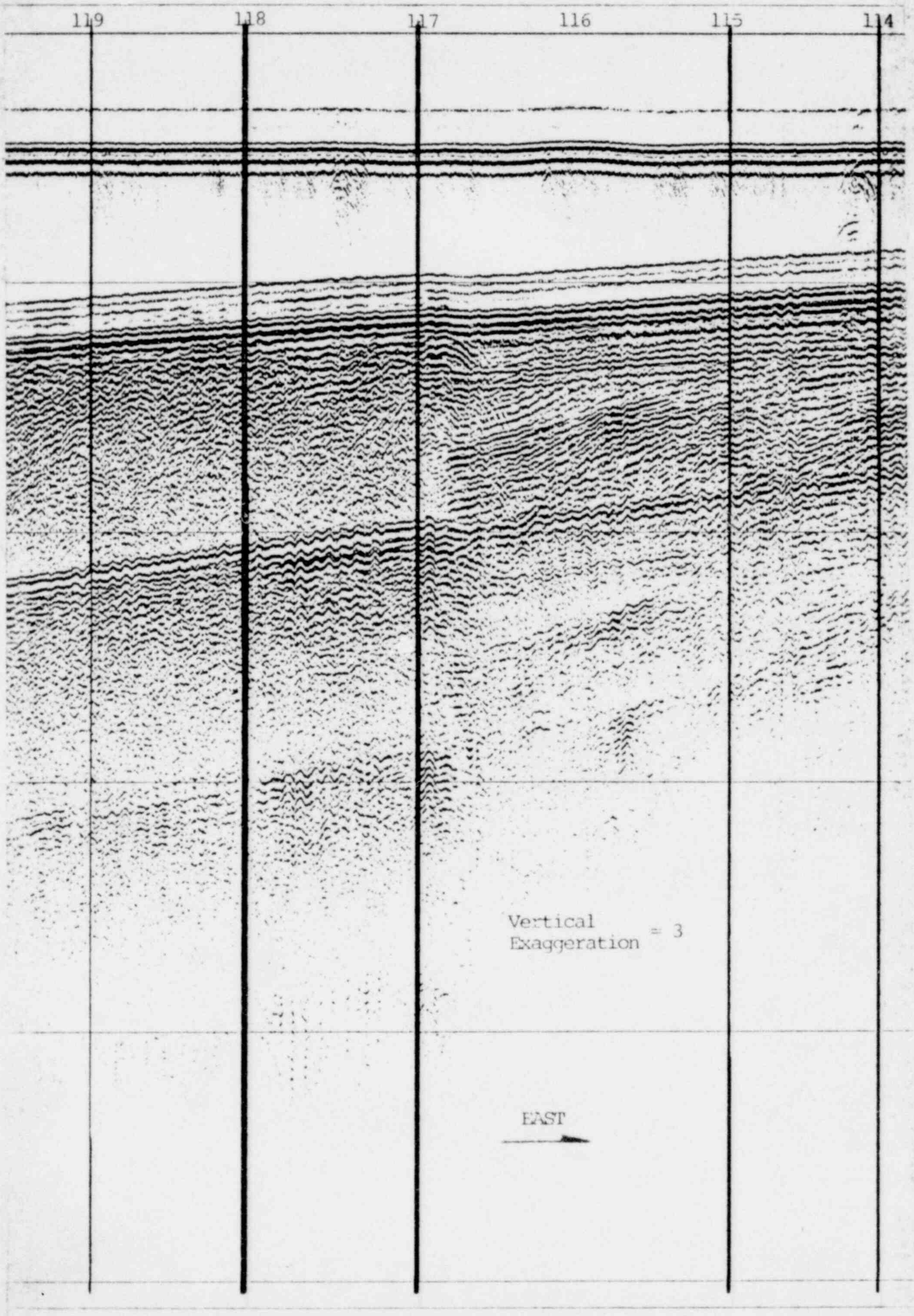


Exhibit V - Watergun Profile, Line 14, Shot Points 114 to 119.

At two line crossings of the zone (shot point 103 on line 12 and shot point 116 on line 14), there appears to be vertical displacement or warping of the youngest terrace deposits amounting to about 3 to 4 msec. (2.5 to 3.4 metres or 8 to 11 feet) (see Exhibit V). Along the northerly portions of the O.Z.D. (as mapped), the Pleistocene erosion surface has minor local elevation differences. These may result from either differential erosion or from faulting, but the younger terrace deposits above these points appear undisturbed. This condition supports the concept that while there appears to be faulting which brought two varying lithologies into juxtaposition, the elevation difference may have resulted from differential erosion. In any event, the absence of displacement in the terrace materials above such contacts suggests that no apparent movement has occurred on the fault at such points for a very substantial period of time.

In the Dana Point survey area (see Map 2B) the O.Z.D. i not present. Numerous gentle anticlines and synclines are evident. Several minor faults were interpreted to be present, but could not be correlated from line to line.

C. Isopach Map(s) of Unconsolidated Terrace Deposits (Maps 3A and 3B). Unconsolidated late Pleistocene or Holocene terrace deposits cover much of the shelf in areas investigated. The maps were prepared from both 3.5 kHz subbottom profiles and watergun profiles. The contour intervals for Maps 3A and 3B are 10 and 5 msec., respectively, of two way travel time measured from seafloor to bedrock. Throughout most of the area, the base of the interval contoured coincides with the late Pleistocene erosional surface (Moore, 1980). Travel times may be converted to sediment thicknesses using an estimated speed of sound of 1675 m/sec (5495 ft/sec) (Hamilton, 1974).

Maximum thickness of the terrace materials is 17 msec. (14 metres or 47 feet) in the Dana Point area and 43 msec. (36 metres or 118 feet) in the Oceanside area. Sediment thickness decreases to zero near the shelf break and near the shoreward limit of the northern survey lines. Farther shoreward, the beach sand would be found.

In the Oceanside area isopachs of the terrace deposits reflect the presence of the O.Z.D. along one-half of its mapped length (see Map 3A). Along the southern portion, terrace sediments immediately east of the zone are commonly 10 msec. (8.3 metres or 27 feet) thicker than those west of the zone. This thickness difference tends to diminish in a northerly direction, and along the northern-most survey lines (lines 28 and 30) there is no change in sediment thickness across the zone.

On lines 12 and 14, slight displacements of the seafloor also reflect the position of the buried fault (see Exhibit VI). If they represent displacements, the movement is apparently up on the west and down on the east. Faint inflections in the slope of the seafloor at the fault crossing are visible on a few of the other lines also. These are best seen on the 3.5 kHz subbottom profiles.

D. <u>Shallow Fault and Structural Trend Map(s)</u>. Maps 4A and 4B were prepared from the watergun profiles. Structural trends below the Pleistocene unconformity have been mapped by line-to-line correlation of anticlinal and synclinal axes. Among fault criteria used were offset reflectors, confused appearance of reflectors, apparent changes of dip, and the absence of reflectors. An absence of defineable reflectors in much of the area west of the O.Z.D. is attributed to massive bedding in the San Onofre Breccia, contorted steeply dipping beds, or both.

The seismic instruments employed in this survey are designed for maximum resolution of detail from the seafloor to a maximum depth of 200 msec. (168 metres or 550 feet). In general, the geology below the unconformity appears to be quite complex. Along most of the shelf in the areas surveyed, there appear to be numerous small folds, depositional disconformities, and a substantial number of small localized faults.

In the northeastern portion of Map 4A (Oceanside survey area), there is a series of small northwest-southeast trending anticlines and synclines. Associated with those gentle folds, we have mapped several short faults. None of the faults are interpreted to displace the Pleistocene terrace deposits, and they may not even extend up to the Pleistocene unconformity. The style of reflections does not indicate that different lithologies have been juxtaposed.

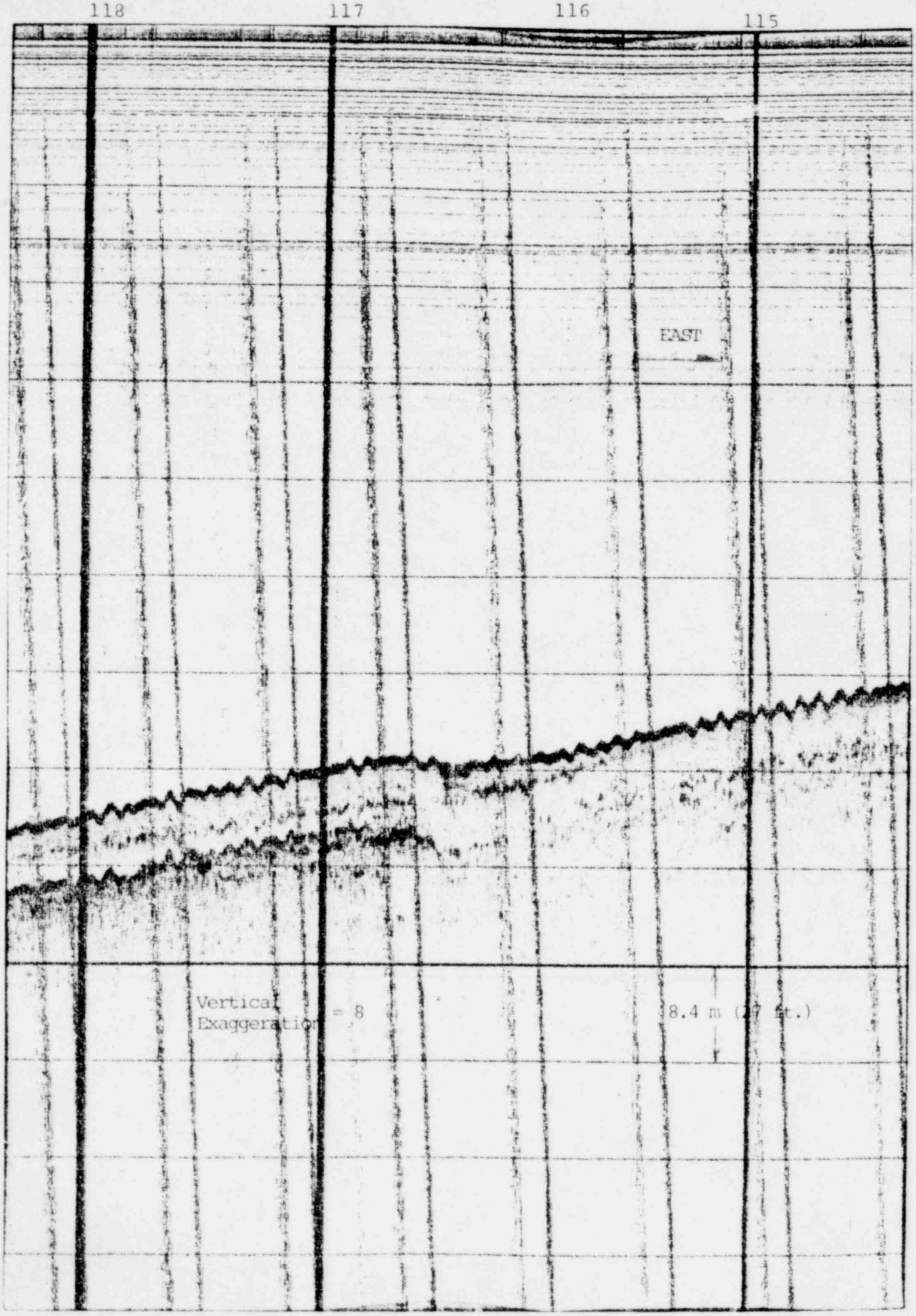


Exhibit VI - 3.5 kHz Subbottom Profile, Line 14, Shot Points 115 to 118

Thus, there is no evidence to connect the Cristianitos Fault with these faults and folds.

In the Dana Point map area, several faults are interpreted to be present on separate lines, but could not be connected. The O.Z.D. was not identified on profiles in the Dana Point area.

E. The Seafloor and Water Column Anomaly Map(s). Maps 5A and 5B were constructed using data from the side scan sonar system and the 3.5 kHz subbottom profiler. The side scan data is from a survey conducted on June 6th and 7th, hence shot point locations are somewhat different than those on Maps 1 through 4.

Several low-relief gullies near the shelf break in the Oceanside area are the main features present. They are perpendicular to the slope and apparently extend downslope beyond the limit of side scan coverage. Associated with gullies in the central part of the Oceanside area are many small bottom targets. These targets are thought to be man-made objects related to military activity in the area, or they may be small patches of boulders or cobbles. Other isolated bottom targets in the area are likely of the same origin. Identifiable bottom targets include the Dana Point sewer outfall and several areas of outcrop in the Dana Point area and at the northern end of the Oceanside area.

Numerous small water column anomalies, possibly gas bubbles or fish, occur in both areas.

V. SIDE SCAN SONAR SURVEY AND SEAFLOOR DIVING INSPECTION

A survey with side scan sonar, followed by spot inspections of the seafloor by two geologists equipped with scuba gear were conducted offshore south of the San Onofre facility. This survey's purpose was to search for surface exposures of bedrock which might indicate the presence of the Cristianitos fault. A 21-foot inboard motor boat from Oceanside, California was used for both operations. The survey grid consisted of 12 lines 3.0 km (1.9 miles) along, separated by intervals of 200 m. (656 feet) (see Exhibit I). The lines were oriented parallel to the coastline, and began approximately 600 m. (1969 ft.) southeast of the power plant. Two lines nearest to shore (100 and 102) could not be run because of shallow water. The three lines farthest from shore (118, 120 and 122) were not completed to the northwest end because of kelp beds. Surveying began on May 7, 1980 and was completed the next day with 27.0 km (19.6 miles) of line surveyed at an average survey speed of 7.2 km./hr. (3.9 knots). A Motorola MiniRanger III system provided navigation for the survey.

Stations selected for inspection by scuba-equipped geologists were chosen to examine anomalous returns on the side scan sonar records and to provide a representative sampling of the area surveyed. On May 9, 21 dives were completed (identified by numbers) and on May 13, 20 dives were completed (identified by letters). MiniRanger III navigation was used to locate the dives.

The Bottom Sediment Type Map (Map 6) was constructed from side scan sonar records and diver's logs. Computations for the shot point fixes were done by Nekton. The map is plotted at a scale of 1:1500 without stepback, but a 7.6-metre (25-foot) stepback has been applied to the side scan data. Due to the shallow tow depth, the ship's wake and other sea surface noise are commonly found on the records as dark wavey returns.

Neither surface expression of faulting nor any unusual bottom features were found on the side scan sonar profiles or by the scuba divers. In the western part of the survey grid, several areas were clearly defined on the side scan records by darker returns. These areas were identified by the divers as having boulders and cobbles, usually with kelp. The numerous water column anomalies present are probably fish swimming near the kelp.

Surface sediments in the area are controlled by several factors: first, the presence of boulders and cobbles weathered out of the San Onofre Breccia, and second, the season. Generally speaking the boulders and cobbles do not move. However, their distribution appears to change due to the seasonal movement of a sheet of fine sediments. In summer, the fine sediments -- very fine sand and very fine silty sand in this area -- move relatively inshore and create larger beaches. In the winter, the fine sediments move relatively offshore and cover up some of the boulders and cobbles.

VI. SUMMARY

Conclusions resulting from the work documented in this report are as follows:

a) At indeterminate periods prior to development of an erosional unconformity during late Pleistocene time, the Tertiary age beds along the coastal shelf near Oceanside were subjected to substantial folding and faulting. Since the development of the erosional surface, the area has been essentially stable.

b) A fault identified in the Oceanside survey area as a part of the O.Z.D., shows evidence of minor movement which locally displaces sediments at the seafloor. There is other evidence, however, that the overall O.Z.D. (as mapped) is not an active zone of detectable movements, i.e., the overlying terrace deposits elsewhere along the zone appear undisturbed.

c) There is no evidence that the onshore Cristianitos Fault joins with, or is a branch of, the O.Z.D. offshore. This conclusion is based upon good quality profiles which cover the projected southerly extension of the Cristianitos Fault into the Oceanside survey area. The profiles also indicate that there is no other fault which intersects the O.Z.D. in this area.

d) Profiles in the Dana Point survey area show that the O.Z.D. is absent, and that the area has been stable since formation of the Pleistocene erosion surface.

REFERENCES

Hamilton, E. W., 1974, Prediction of deep-sea sediment properties: state-of-the-art: in Deep-Sea Sediments, A. L. Inderbitzen (editor), Plenum Press.

Moore, D. G., 1980, personal communication.

Speidel, W. C., 1975, Nearshore sediments at San Onofre California: in Studies on the Geology of Camp Pendleton and Western San Diego County, California, A. Ross and R. J. Dowlen (editors), San Diego Assoc. of Geologists, p. 36-50.

Intertretation, maps and written report prepared by:

NEKTON, INC.
San Diego, California

Approved by:

Carroll L. Hoyt
General Manager

APPENDIX 1 -- FIELD OPERATIONS

Survey Vessel

Profiling operations for the Oceanside and Dana Point areas were conducted from the research vessel SEAMARK (length 33.2 metres and beam 7.3 metres), owned and operated by Nekton, Inc., San Diego, California. The vessel is fully outfitted for high resolution profiling. Two separate laboratories provide space for recorders and system's electronics. The vessel accommodates twenty-two personnel for periods of up to two weeks at sea.

Personnel

Ship's crew for round-the-clock operations numbered six men including the Master, Robert Witten. Technical personnel, including electronics and profiling technicians, totaled six men under the supervision of the Manager of Seismic Operations, William C. Speidel. Additionally, there were two navigators responsible for the operation of the precision electronic positioning system.

Liaison and ship support functions were the responsibility of William Watts, the contractor's Manager of Marine Operations.

Survey Grid

Survey operations were conducted over a grid suggested by J. L. McNey of Southern California Edison Company and D. G. Moore, consultant to Edison Company. The principal grid lines in the Oceanside and Dana Point areas are oriented northeast-southwest with one northwest trending tie line in each area. Shot point fixes were recorded along each line at 150-metre (492-foot) intervals. The total distance covered in these two areas was 115 km (71.5 miles). (See Exhibit I).

Positioning Services

All positioning services, including preplot coordinates, ship navigation, fix mark recordings, postplot computations, and map plotting, were provided by Navigation Services, Inc. A Motorola MiniRanger III system was used aboard ship.

Date of Survey Instrumentation and Field Conditions

Survey operations were conducted in the area on June 6 and 7, 1980. Poor data quality due to instrument problems necessitated subsequent reacquisition of most of the data on June 15 and 16.

Instrumentation for the survey included a 3.5 kHz system for shallow detail, side scan sonar for mapping surface features along the seafloor and a 15 cubic inch watergun for high resolution seismic data. The watergun was fired at 0.5 sec. intervals to enhance recording of detailed structure and minimize vertical exaggeration.

Side scan sonar data from the earlier operations have been used for interpretation while watergun and 3.5 kHz subbottom profiles from the latter survey were used. Calm sea conditions prevailed during both survey periods and posed no operational problems. The presence of fishing gear in the area did pose a hazard to side scan sonar operations and as a result, some of the grid lines could not be surveyed along the preplotted track.

APPENDIX 2 - GEOPHYSICAL SYSTEMS

During parts of this survey three separate acoustic profiles were recorded simultaneously. These were as follows:

1) Watergun - 0.5 second receive gate, single channel analog profile.

2) 3.5 kHz Profiler - 0.25 second receive gate.

3) Dual channel side scan sonar - horizontal scale of 200 metres (656 feet) per channel.

The description and operational settings for each system are as follows:

1) Watergun System

A. Source: Seismic Systems, Inc.'s 15 cubic inch water gun sound projector. The gun was towed 43.5 metres (142.5 ft.) behind the positioning antenna at a depth of 1.0 metre (3 feet) and fired every 0.5 sec.

B. Detector: Data recorded from one channel of a two-channel hydrophone constructed by Nekton, Inc. Each channel consisted of twenty geophones in a linear tapered array. Lead end of the active section was 53.5m (175.5 feet) behind the positioning antenna.

C. Filters: 200 Hz low cut, 400 Hz high cut.

D. Recorder: EPC Labs Model 4600 Graphic Recorder operated at receive gate of 500 ms.

E. Vertical exaggeration: 4

F. Scale: 375 m (1230 ft) at speed of sound in water of 1500 m/sec. (4921 ft/sec.).

2) 3.5 kHz Subbottom Profiler System

A. Source/Detector: O.R.E. Model 1036 transducer towfish towed 15 metres (49 feet) behind the positioning antenna at a depth of 3 metres (10 feet). Source fired every 0.25 or 0.5 sec. Unit operated at power of 9 kw.

B. Recorder: EPC Labs Model 4600 Graphic Recorder operated at receive gate of either 250 ms or 500 ms.

C. Vertical exaggeration: 8

D. Scale: 187 m or 375 m (615 or 1230 feet) at speed of sound in water of 1500 m/sec. (4921 ft/sec.)

3) Side Scan Sonar System (Oceanside and Dana Point areas)

A. Source/Detector: EG&G Model 272 dual channel 105 kHz transducer towfish towed between 40 and 250 metres (131 and 820 feet) behind the positioning antenna.

B. Recorder: EG&G SMS-960 microprocessor-based system. Generates plan view image of seafloor by automatically correcting slant range and speed distortion. Operated at horizontal range of 200 metres (656 feet) per channel.

C. Records of cable deployed maintained on sonargrams.

4) Side Scan Sonar System (San Onofre area)

A. Source/Detector: EG&G Model 272 dual channel 105 kHz transducer towfish towed 7.6 metres (25 feet) behind the positioning antenna.

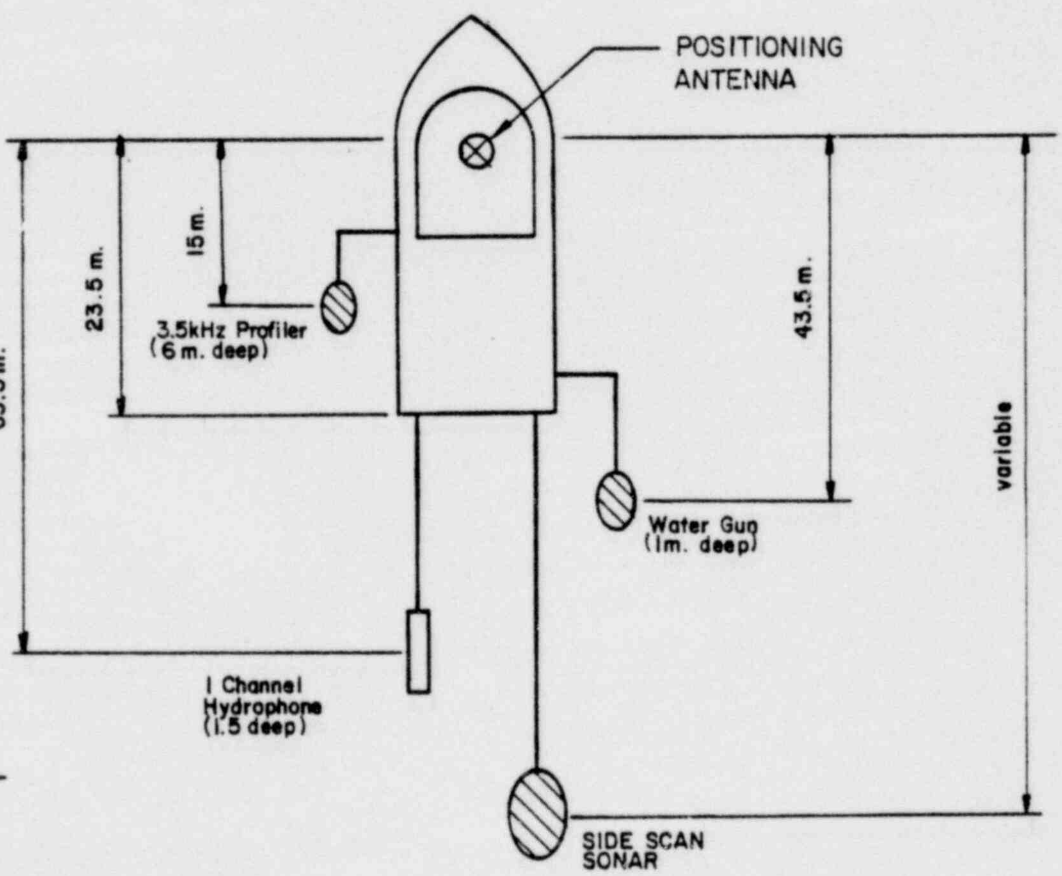
B. Recorder: EG&G Model 259-r two-channel recorder operated at slant range of 200 metres (656 feet) per channel.

C. Distortion parallel to line of travel approximately 50% compression at survey speed of 5 knots.

NEKTON INC.
SAN DIEGO, CALIF.

Client: SOUTHERN CALIFORNIA EDISON COMPANY
Title: *Survey Systems Layout M/V Seamark*

30 June 1980



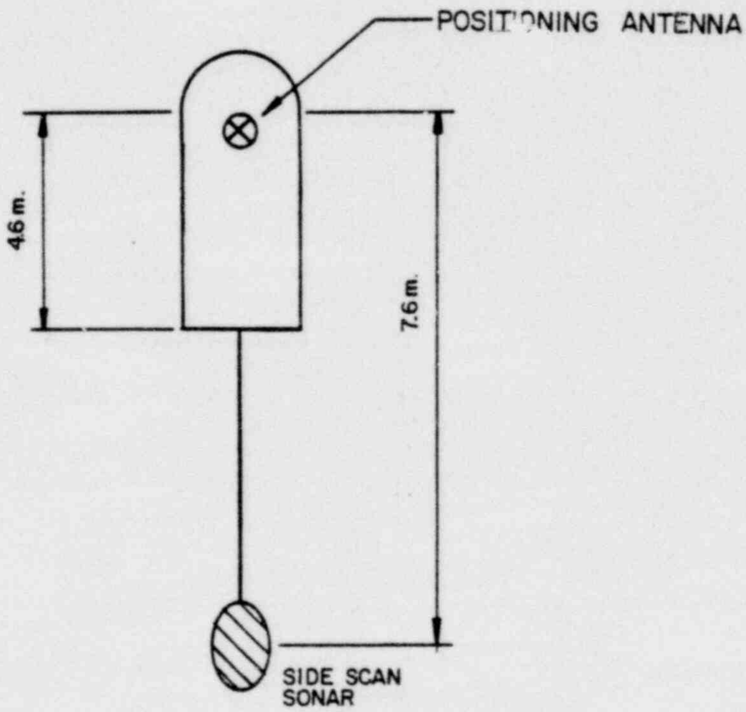
m.	ft.
1	3
1.5	5
6	20
15	49
23.5	77
43.5	143
63.8	208

NEKTON INC.
SAN DIEGO, CALIF.

Client: SOUTHERN CALIFORNIA EDISON COMPANY

Title: *Survey System Layout*
21-Foot Motor Boat

30 June 1980



m.	ft.
4.6	15
7.6	25