16

GEOLOGIC REPORT ON THE PROBABILITY OF GROUND DISPLACEMENT ON FAULTS IN THE VICINITY OF THE SAN ONOFRE NUCLEAR POWER PLANT SITE UNITS 2 AND 3 SAN DIEGO COUNTY, CALIFORNIA

Conducted For

SOUTHERN CALIFORNIA EDISON COMPANY
601 West Fifth Street
Los Angeles, California

See Amdt 17 FSAR

Project No. 70-034-AH
April 30, 1970

CONVERSE, DAVIS AND ASSOCIATES

Consulting Engineers and Geologists

126 West Del Mar Boulevard, Post Office Box 2268D, Pasadena, California 91105

Telephone (213) 681-1121

196

Consulting Engineers and Geologists

CONVERSE, DAVIS AND ASSOCIATES

126 West Del Mar Boulevard, Post Office Box 2268D, Pasadena, California 91105 Telephone (213) 681-1121

April 30, 1970

Southern California Edison Company
601 West Fifth Street
Los Angeles, California 90053

Attention: Mr. Gail Hunt

Gentlemen:

Transmitted herewith is our "Geologic Report on the Probability of Ground Displacement on Faults in the Vicinity of the San Onofre Nuclear Power Plant Site, Units 2 and 3, San Diego County, California."

The investigation described in the report included geologic mapping, detailed logging of excavations, comprehensive literature review and other related studies. Based on the geologic studies, it is our opinion that the probability of ground displacement within the plant site during its lifetime is very low.

This investigation was performed under the general supervision of Mr. Roy A. Hoffman, Jr., Principal Geologist. Mr. John D. Scott, Project Geologist conducted and supervised field geologic studies performed by Mr. Paul Davis and Mr. Ron Nicks, Staff Geologists.

We appreciate working with you on this most interesting project.

Sincerely,

Jay L. Smith
Vice President

RAH/JLS:eg

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

1. INTRODUCTION

In accordance with authorization from the Southern California Edison Company, a geologic investigation was made of the site for proposed Units 2 and 3 of the San Onofre Nuclear Power Plant, San Diego County, California.

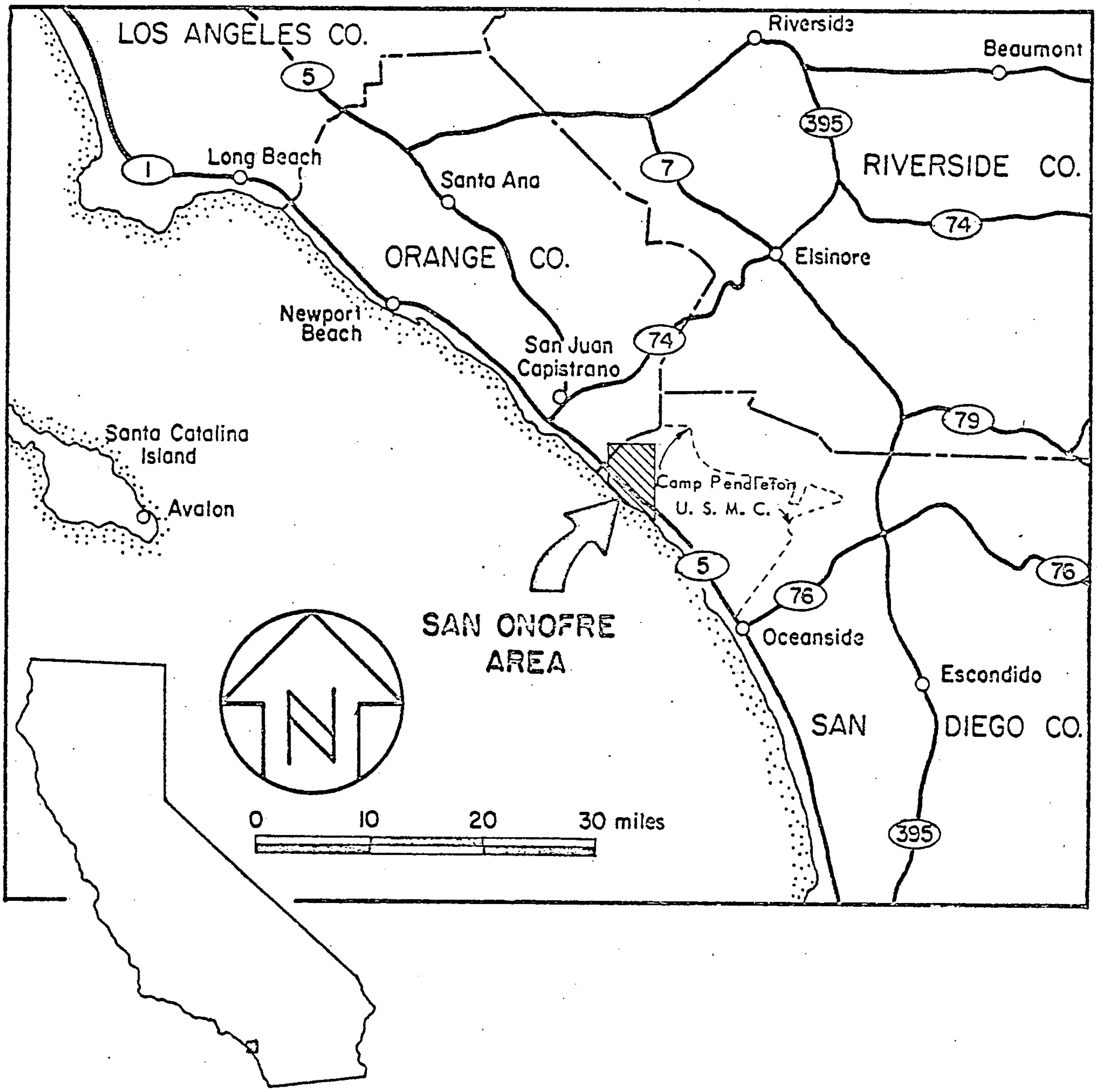
1.1 Location of Site

As shown in Figure 1, Vicinity Map, the Power Plant is adjacent to San Onofre Beach, on the northwest end of Camp Pendleton Marine Corps Base and four miles southeast of the limits of the City of San Clemente. The proposed Units 2 and 3 will be directly south of the existing Unit 1, and will occupy a graded site where the switch racks and the visitor center now stand.

1.2 Scope of Investigation

This report describes an investigation of geologic conditions pertinent to evaluating the probability of ground displacement on faults in the vicinity of the San Onofre site. The investigation included the following:

1. Review of previous investigations conducted for Unit 1 of the San Onofre Power Plant.
2. Detailed examination and logging of an exploratory excavation across a branch of the Cristianitos fault in Plano Trabuco (see Appendix D).
3. Detailed examination and logging of an exploratory excavation at San Onofre Bluffs across the Cristianitos fault at its southernmost exposure (see Appendix C).



VICINITY MAP OF THE SAN ONOFRE AREA

Figure 1

4. Detailed examination and logging of the seacliff between the plant site and the Cristianitos fault to the south (see Appendix B).
5. Geologic mapping along the Cristianitos fault from the beach to San Mateo Canyon and that area extending westward to the shoreline.
6. Field examination for other faults that might project toward the site.
7. Review of published and unpublished literature on the geology of the region.
8. Examination of aerial photographs.
9. Radiometric dating of shell fragments from marine terraces.
10. Review of data and interpretations from offshore sparker surveys by Marine Advisors, Inc.
11. Review of subsurface data from a boring and geophysical (seismic refraction) studies by Dames and Moore, Inc.

Field studies by Converse, Davis and Associates began with detailed logging of the Plano Trabuco excavation in December, 1969. This work was followed by the logging and mapping studies in the immediate vicinity of San Onofre.

A geologic map was prepared by mapping on aerial photographs and transferring the data to an enlarged portion of the U.S.G.S. topographic map of the San Onofre quadrangle. The mapping was done at a scale of 1 inch to 1000 feet and the final map is attached in Appendix A at a reduced scale as Drawing No. 1.

2. CONCLUSIONS

Based on the investigation described in this report, the following conclusions are made:

1. No faults were found in the Pliocene San Mateo Formation comprising the foundation rock of the site, and no evidence was found to suggest that buried faults exist at depth beneath the site nor that projections of other faults extend into the site. Accordingly, in our opinion the probability of ground displacement within the plant site during its lifetime is very low and does not warrant specific design nor location of Units 2 and 3 to accommodate or avoid such an occurrence.
2. The Cristianitos fault is the closest fault to the site and is approximately 3/4 mile east of Unit 3. This fault has not had displacement at the ground surface for at least 80,000 years, and probably not for at least a few hundred-thousand years. Historic earthquakes cannot reasonably be associated with this fault, and the seismicity of this region is low. Accordingly, in our opinion the probability of ground displacement on the Cristianitos fault during the life of the San Onofre Nuclear Power Plant is very low.
3. The San Onofre Nuclear Power Plant site is approximately 60 miles from the San Andreas fault, 45 miles from the San Jacinto fault, 23 miles from the Whittier-Elsinore fault, and 5 miles from the offshore projection of

3. REGIONAL FAULT RELATIONSHIPS

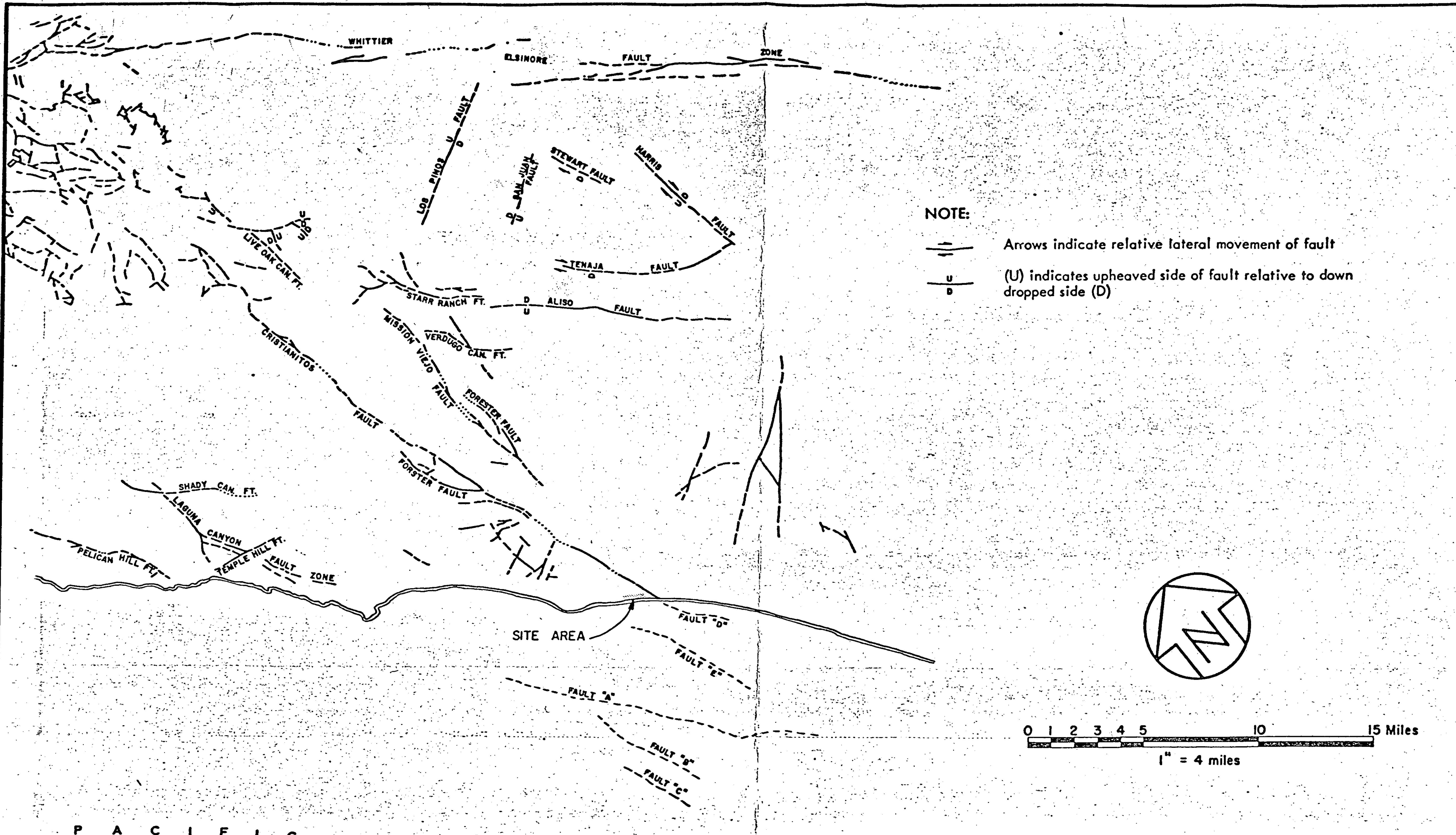
3.1 Geologic Setting

The geology of southern California is dominated by northwest trending right-lateral faults, principally the San Andreas and San Jacinto fault system, which exhibits large displacements, abundant evidence of numerous Quaternary displacements, and a high degree of seismic activity. This and other parallel fault systems form the boundaries of large crustal blocks hundreds of miles in length. The San Andreas and San Jacinto faults are 60 and 45 miles, respectively, northeast of the site.

The Peninsular Range Geomorphic Province of California in which the site is situated, is characterized by northwest trending faults and physiographic features that extend southward into Mexico. The Santa Ana Mountains are within this province and form a block bounded by major faults--the Whittier-Elsinore on the east and the Newport-Inglewood on the west. This mountain block contains faults with north-south to east-west trends that are of relatively short length with less displacement, little evidence of Quaternary displacements and very low degrees of seismic activity.

3.2 Regional Mechanics

The region most pertinent to study is considered to be the crustal block of the Santa Ana Mountains bounded by the Whittier-Elsinore and offshore fault or faults, between the Santa Ana and Santa Margarita Rivers. This block and the principal elements of faulting within it are shown on Figure 2. The Santa Ana Mountains



REGIONAL FAULT MAP			
PREPARED BY: JDS - GDT	PROPOSED SAN ONOFRE NUCLEAR POWER PLANT Units 2 and 3 for Southern California Edison Company		FIG. NO. 2
CHECKED BY: JDS			
APPROVED BY: RAH	DATE: Apr. 13, 1970	SCALE: As Shown	PROJECT NUMBER: 70-034-H
CONVERSE, DAVIS AND ASSOCIATES	PASADENA • SANTA ANA, CALIFORNIA		

consist of granitic and volcanic rocks with marine sediments of Cretaceous to Pleistocene age on the southwest flank, extending to the coastline. The general structure on the flank of the mountains is a southwest-dipping homocline interrupted by nearly north-south trending faults and folds.

Displacement on the Elsinore fault has been greater than on the Newport-Inglewood fault, causing the Santa Ana Mountain block to move northwest against the Puente Hills which are bounded on the west by the Whittier fault. A dense pattern of compression or tear faults exists in the area where the Whittier-Elsinore faults connect in Santa Ana Canyon. Horizontal and vertical movements on the Elsinore fault produced vertical displacements at the northwest end of the block to form the Cristianitos fault. These vertical displacements on the Cristianitos fault decrease southward, possibly dying out offshore before reaching Fault "A," suggesting a hinge type of fault mechanism.

3.3 Faults

3.3.1 Elsinore Fault

The Elsinore fault is a high angle reverse fault approximately 120 miles long with about 1000 feet of right lateral movement (Mann, 1955), and a Minimum of 5000 feet of vertical displacement (Gray, 1961). Major movement occurred in Post-Pleistocene time with the latest movement occurring since the end of Pleistocene time. The seismic record indicates only very low activity, generally south and east of the site. The Whittier fault is a continuation of the Elsinore fault with similar movement and relationships and has been included in the total fault length.

3.3.2 Newport-Inglewood Fault

This fault is mainly defined by subsurface data and has a northwest trend with right lateral displacement of 3000 to 5000 feet, and vertical displacement of 4000 feet of the basement rocks with only 200 feet at the Plio-Pleistocene contact (Yerkes et.al., 1965). The fault has an onshore length of about 48 miles where it is inferred (Emery, 1960; Albee, Smith, 1966) to continue toward San Diego. Although no surface ground displacement is known to have occurred from the 1933 Long Beach earthquake, the seismic record appears to indicate continued activity along the onshore segment of this fault.

3.3.3 Cristianitos Fault

The Cristianitos fault is a normal vertical fault with the east side up. Maximum displacement of 5000 feet is reported by Fernandez (1959) near its midpoint with a minimum of 900 feet near San Onofre. The major movement would appear to have occurred in the Pliocene or early Pleistocene, depending upon the age of the San Mateo Formation. The minimum age of last movement on the fault would be prior to deposition of the marine terrace (Southwick, 1928). No historic earthquakes can be reasonably associated with the Cristianitos fault and the seismic record further indicates the region is inactive. The Mission Viejo fault is east of the Cristianitos fault and is similar in mechanics and orientation but smaller in displacement and length (Oates, 1960; Roth, 1958).

3.3.4 Offshore Faults

Interpretation of offshore geophysical sparker surveys by Marine Advisors, Inc., reveal about five faults that could be traced for more than one mile. These have been designated Faults "A," "B," "C," "D" and "E." Faults "B" and "C" appear to be related to the larger Fault "A," although none of these faults could be extended northwest beyond Dana Point with any assurance. The possibility exists that these faults may represent the offshore extensions of the Pelican Hills and/or Laguna Canyon faults. Fault "D" trends north to north-northwest nearly parallel to the shoreline to join the onshore Cristianitos fault. Fault "E" also trends north-northwest but rather than connecting with the Cristianitos fault, it either terminates or goes ashore near the mouth of San Mateo Canyon. No evidence for the onshore faults in this area could be found.

3.3.5 Other Faults in the Region

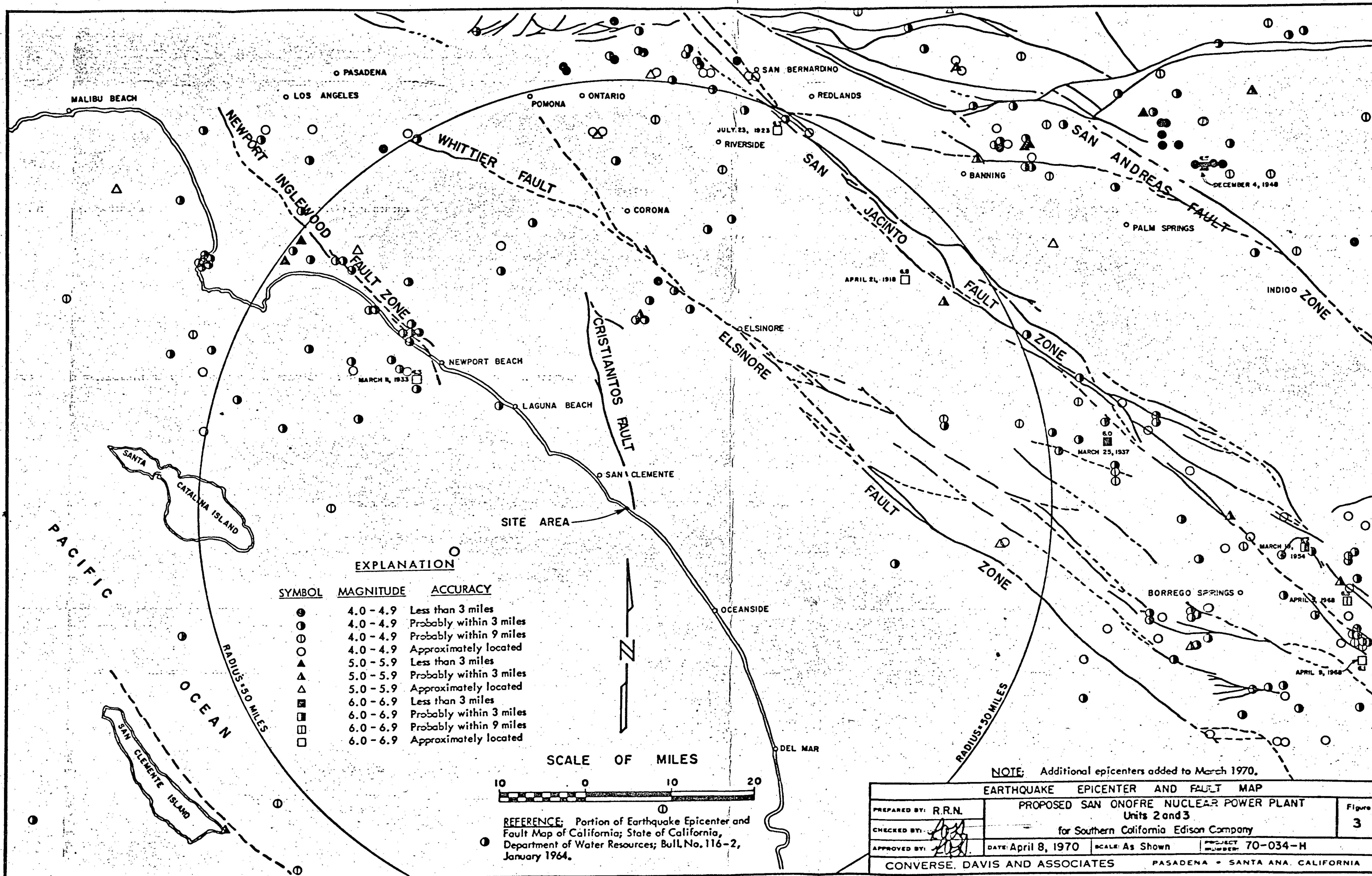
Other faults exist throughout the crustal block but are secondary in nature or related to folding in areas adjacent to the block. The Los Pinos, San Juan and other northeast trending faults east of the Cristianitos fault are transverse to the line of uplift along the Elsinore fault. The predominantly northwest trending faults in the San Joaquin Hills area, including the Laguna Canyon, Shady Canyon and Pelican Hill faults appear to be related to the San Joaquin Hills anticlinal uplift. The Pelican Hill fault may have movement with lateral separation similar to that of the nearby Newport-Inglewood fault (Yerkes, et.al., 1965), with movement between early Miocene and late Pliocene times.

3.4 Earthquakes

Despite the high seismic activity of southern California, the San Onofre site lies within an area of relative quiescence. A plot of strain-release in southern California by Allen, et.al. (1965), indicates the site to be within an area of strain-release of 1/4 to 1 earthquake of Magnitude 3.0 or greater per 100 square kilometers during the period between 1934 and 1963. The plot of earthquake epicenters for a radius of greater than 50 miles from the plant site is attached as Figure 3. It is apparent, that proceeding from the site, the significance of faulting increases, the intensity and magnitude of earthquakes increase and the recency of fault ground rupture increases. The largest earthquakes have occurred on the San Andreas-San Jacinto faults, at least 60 and 45 miles distant, respectively, in addition to the fact that no historic ground displacement has occurred on any fault west of these faults in southern California.

3.5 Strain Accumulation

Precise level surveys along the coastal area by the U. S. Coast and Geodetic Survey indicate vertical variations to be less than 0.001 and 0.003 foot per year of subsidence during the period 1933 to 1938. This rate is considered to be almost negligible compared to areas of known subsidence where vertical changes may range between 0.02 and 0.05 foot per year. No geodetic data was


PASADENA
LOS ANGELES
MALIBU BEACH
POMONA
ONTARIO
SAN BERNARDINO
REDLANDS
JULY 23, 1923
RIVERSIDE
BANNING
DECEMBER 4, 1948
PALM SPRINGS
CORONA
APRIL 21, 1918
INDIO
ELSINORE
NEWPORT BEACH
MARCH 11, 1933
LAGUNA BEACH
SAN CLEMENTE
SITE AREA
OCEANSIDE
DEL MAR
MARCH 25, 1937
BORREGO SPRINGS
MARCH 19, 1954
APRIL 9, 1968
NEWPORT INGLEWOOD FAULT ZONE
WHITTIER FAULT
CRISTIANITOS FAULT
ELSINORE FAULT ZONE
SAN JACINTO FAULT ZONE
SAN ANDREAS FAULT ZONE
SANTA CATALINA ISLAND
SAN CLEMENTE ISLAND
PACIFIC OCEAN
RADIUS = 50 MILES
RADIUS = 50 MILES
N
EXPLANATION
SYMBOL MAGNITUDE ACCURACY
4.0 - 4.9 Less than 3 miles
4.0 - 4.9 Probably within 3 miles
4.0 - 4.9 Probably within 9 miles
4.0 - 4.9 Approximately located
5.0 - 5.9 Less than 3 miles
5.0 - 5.9 Probably within 3 miles
5.0 - 5.9 Approximately located
6.0 - 6.9 Less than 3 miles
6.0 - 6.9 Probably within 3 miles
6.0 - 6.9 Probably within 9 miles
6.0 - 6.9 Approximately located
SCALE OF MILES
10 0 10 20
REFERENCE: Portion of Earthquake Epicenter and Fault Map of California; State of California, Department of Water Resources; Bull. No. 116-2, January 1964.
NOTE: Additional epicenters added to March 1970.
EARTHQUAKE EPICENTER AND FAULT MAP
PREPARED BY: R.R.N.
CHECKED BY:
APPROVED BY:
PROPOSED SAN ONOFRE NUCLEAR POWER PLANT
Units 2 and 3
for Southern California Edison Company
DATE: April 8, 1970
SCALE: As Shown
PROJECT NUMBER: 70-034-H
Figure 3
CONVERSE, DAVIS AND ASSOCIATES
PASADENA • SANTA ANA, CALIFORNIA

available from the U.S.C.&G.S. relative to lateral movement. The data and absence of data strongly suggest that the area is one of tectonic inactivity.

4. GEOLOGY OF SITE AND VICINITY

4.1 Investigation

The field investigation of the site and vicinity included: (1) geologic mapping of the site with special emphasis on the Cristianitos fault between the coast and San Mateo Canyon, (2) the excavation and logging of 680 feet of trench along San Onofre Bluffs, (3) the excavation and logging of 140 feet of trench at Plano Trabuco, (4) mapping and logging of the natural cliff exposures at San Onofre about a mile north and south of the existing Unit 1.

Approximately nine days were spent at the site mapping the geology of the triangular-shaped area defined by the coast, San Mateo Canyon, and the Cristianitos fault. The area was mapped on aerial photographs at a scale of 1 inch to 1000 feet and transferred to a topographic map of the same scale. Special emphasis was placed on determining the number of traces associated with the Cristianitos fault between the coast and San Mateo Canyon. In addition, surrounding areas where faults previously mapped by other workers were reexamined to determine whether faults could reasonably be projected toward the site.

About ten days were spent mapping and logging the San Onofre Bluffs excavation (see Figures 4 and 5) and the seacliff north and south of the existing Unit 1. Approximately two days were required to photograph and log the Plano Trabuco excavation (see Figures 6 and 7). In each case, a grid was used to maintain accurate scale and the trench was logged at five feet to the inch and, in certain locations, at two feet to the inch.

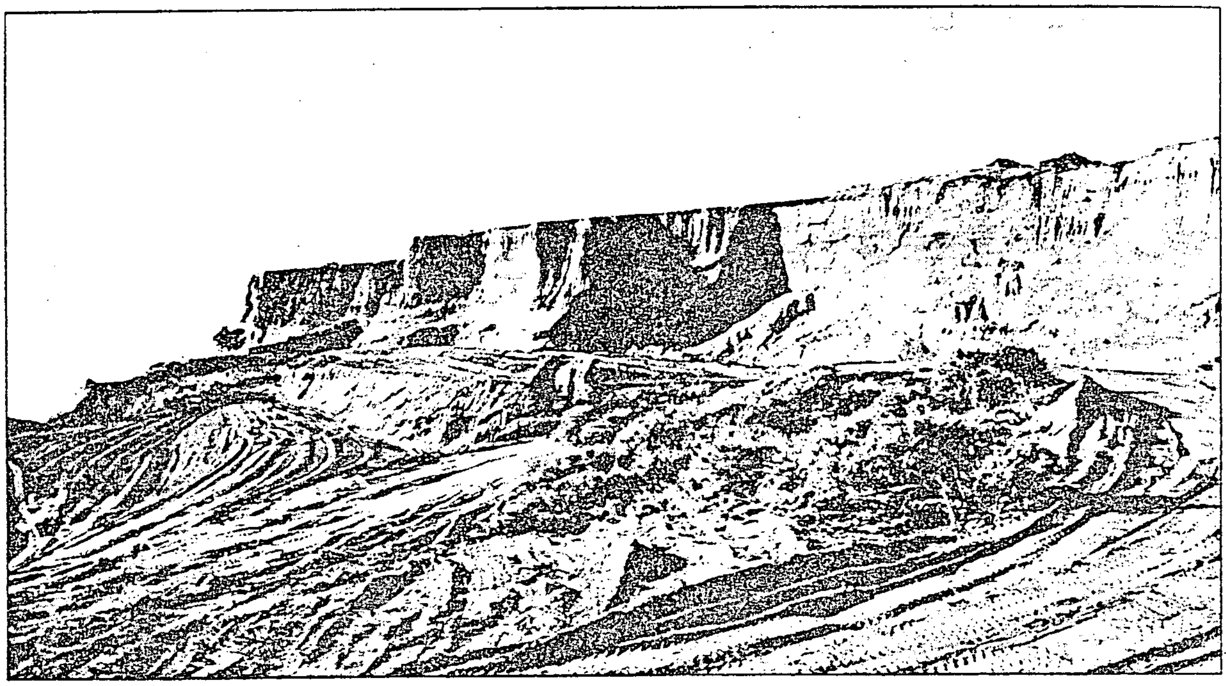


Figure 4

Looking northwest at the San Onofre Bluffs trench. Excavated materials were used to fill the low area on the left side of the photograph.

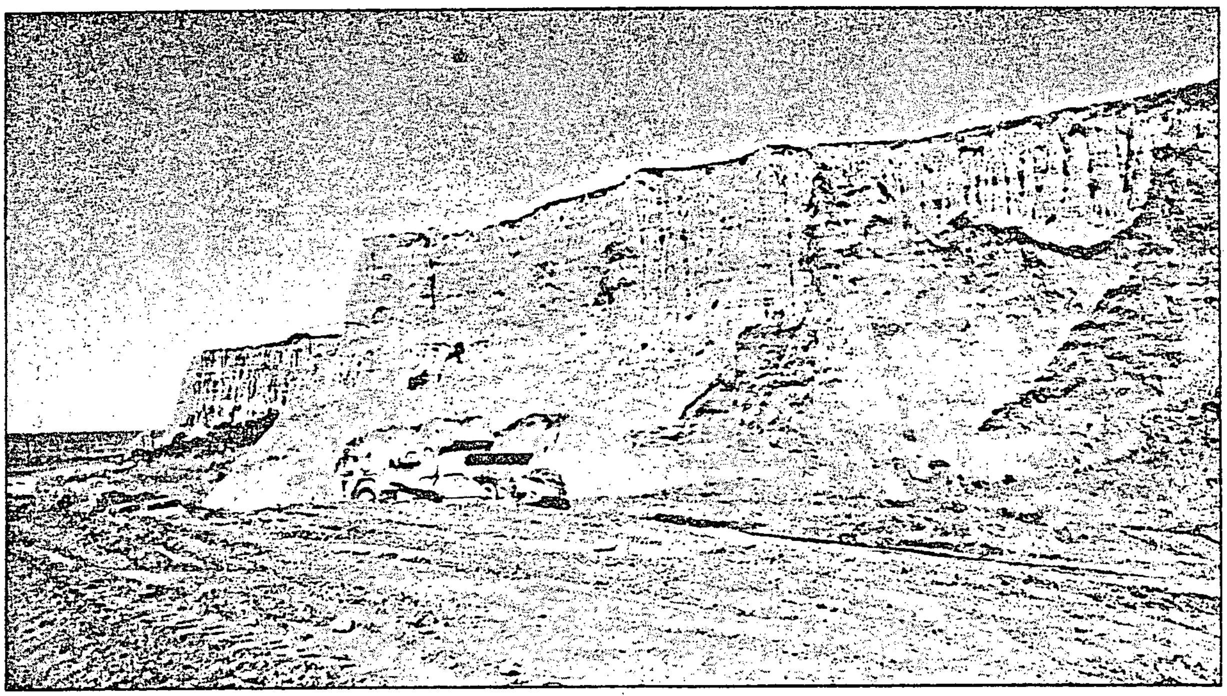


Figure 5

A scraper and bulldozer were used to excavate 680 feet of trench along the base of the bluffs. The scraper is located at approximately Station 525. Station "zero" is located near the toe of the cliff in the background.

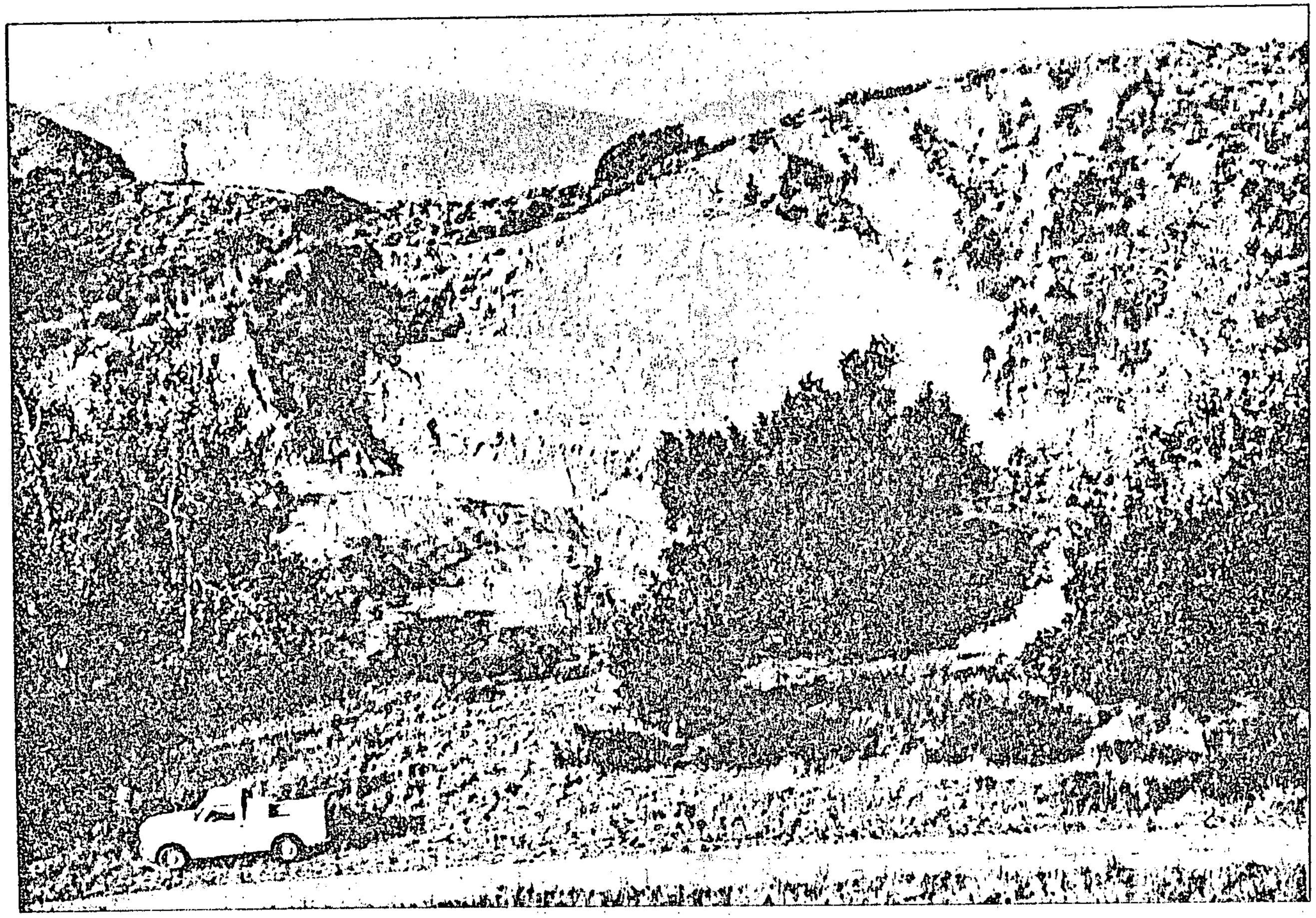


Figure 6

Looking west at the Plano Trabuco excavation. The vertical cut along the toe of the excavation exposes the irregular contact between the overlying brown, non-marine terrace deposits and the light gray Sandstone bedrock.

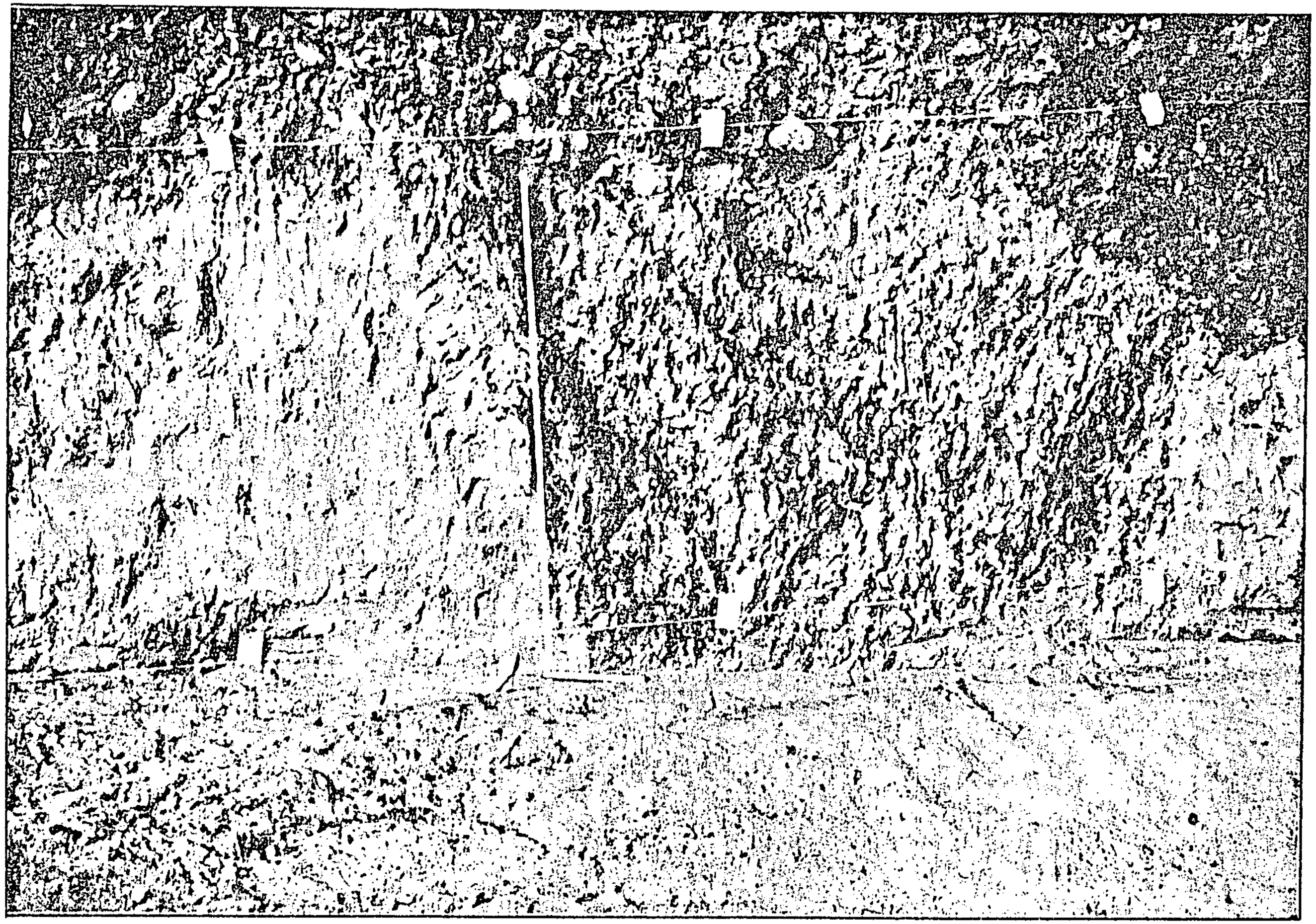


Figure 7

A portion of the Plano Trabuco excavation between Stations 48 and 63 (approximately). The shear surfaces along the sides of the wedge-shaped, chaotic mixture of rubble and clay do not displace the terrace-bedrock contact. A Detail Log of this area is included in Drawing 7.

Several additional trenches were excavated by the Southern California Edison Company at the Plano Trabuco site. These trenches did not reveal any traces of the Cristianitos fault and, therefore, logs were not prepared.

4.2 Lithology

4.2.1 Santiago Formation

The Santiago Formation of Eocene age is the oldest unit exposed in the area under investigation. The formation consists of a coarse to fine grained, white to light gray sandstone. The rock is poorly cemented and erodes easily to form rolling topography with few exposures.

4.2.2 San Onofre Formation

Between the coast and San Mateo Canyon, the San Onofre Formation of Middle to Upper Miocene age is widely distributed east of the Cristianitos fault. The rocks are hard, resistant to erosion and are usually well exposed along the flanks of the major drainage channels.

The formation consists, in decreasing abundance, of breccia, conglomerate, and sandstone. The breccia and conglomerate characteristically contain clasts of blue-green glaucophane schist, which range in size from fractions of an inch to several feet across. The gray and gray-brown sandy matrix material is well cemented and hard. The light brown sandstone is coarse grained, massive to thickly bedded and contains some vertebrate fossils.

4.2.3 Capistrano Formation

The Capistrano Formation of Upper Miocene age is moderately well exposed west of the Cristianitos fault near San Mateo Canyon and is extensively exposed east of the fault in the San Onofre Bluffs excavation. In the northern part of the mapped area, the Capistrano Formation consists of a very thinly bedded, light gray and light gray-brown shale. The rock is moderately hard, fissile and is slightly resistant to erosion. The topography is characteristically low, rolling hills marked on the canyon walls by numerous landslides. Two isolated outcrops of white diatomite and diatomaceous siltstone were mapped east of the Cristianitos fault and were tentatively assigned to the Capistrano Formation, since diatomite was also observed in the excavation along the coast.

In the San Onofre Bluffs excavation, the Capistrano Formation consists of dark brown, brown and dark gray, laminated clayey siltstone and thinly bedded siltstone. Thin layers of light gray sandstone, tuff, diatomite, bentonitic tuff and concretions are interbedded with the clayey siltstone.

4.2.4 San Mateo Formation

The San Mateo Formation of Pliocene to Pleistocene (?) age is widely distributed west of the Cristianitos fault, is well exposed along the coast, and underlies the existing and proposed San Onofre Nuclear Plant units. The rocks are predominantly massive, light brown to light gray, arkosic sandstones with scattered interbeds of rounded gravel, and layers of fine silty sandstone and siltstone. The sandstone is poorly cemented but is dense and forms steep canyon walls and near-vertical cliffs along the coast. Locally, large fragments of siltstone, up to 3 feet by 9 feet, have been incorporated into the San Mateo sandstone by turbidity currents or submarine slumping during Pliocene time.

In the gravel-pit excavation at the bend of San Mateo Canyon, a thick, lenticular layer of gray-brown conglomerate is interbedded between light brown, dense sandstones. The rounded pebble and cobble size clasts are predominately glaucophane schist and various igneous rocks, indicating they were derived from the San Onofre Formation and other rock types inland. The gray-brown, dense sandy matrix also contains small fragments of glaucophane schist.

The gravel-pit excavation along the west flank of the point in San Mateo Canyon exposed a gray-green siltstone unconformably overlying the San Mateo sandstone, indicating locally that some siltstone interbeds exist.

Recent drilling by Dames and Moore near the existing San Onofre Nuclear Plant indicates the San Mateo Formation is at least 900 feet thick at that point along the coast. Based upon the drilled section and mapping, the total thickness of the formation is inferred to be approximately 2000 feet.

4.2.5 Terrace Deposits

Two types of non-marine terrace materials have been recognized in the area mapped: (1) a series of crudely stratified mixtures of brown to gray-brown sand, silt, and clay, with scattered lenses and layers of gravel, cobbles, and some boulders

(Qt_1); and (2) a mixture of gravel, cobbles, and boulders in a red-brown silty sand matrix (Qt_2).

Qt_1 is representative of the thick accumulations of brown, slightly organic terrace materials exposed in the coastal bluffs. These materials were deposited over the wave cut benches of Pleistocene age. Source material for the terrace deposits was detrital debris from the foothills. Thickness of these deposits varies from 30 to 50 feet.

Along the base of the terrace deposits extends a continuous layer of cobbles and boulders about three to five feet thick in a coarse light gray sand matrix. Along the coast this unit interfingers with fine to coarse sand, and gravel, which inclines gently seaward. Although no fossils were found locally in this unit, mollusks have been receovered from similar deposits about five miles south, which, together with bedding and sorting characteristics, and correlation with coastal terraces elsewhere, clearly indicate the marine origin of this unit (Southwick, 1928).

Qt_1 is also deposited along the low flanks or flood plains of San Mateo and San Onofre Creeks. In these areas the deposits are brown and gray-brown sandy silt with fewer gravel and cobble layers. Most of these broad, gently dipping terrace slopes are being cultivated.

Qt_2 is stream-deposited terrace debris consisting of red-brown gravel, cobbles and scattered boulders in a silty sand matrix. These deposits usually cover small knobs and occupy narrow benches along the flanks of San Onofre and San Mateo Canyons.

The coarse texture and distinctive color distinguish this deposit from Qt_1. Qt_2 also covers the terrace bench above the coastal plain east of Unit 1. The deposits appear to be fans derived from the breccia exposed in the San Onofre Mountains to the east. The thickness of these deposits is not known.

4.2.6 Landslide Deposits

Many of the canyon walls in the area under investigation are marked by landslides. These rounded, hummocky features along the canyons are especially evident in areas underlain by the Capistrano and Santiago Formations and along those canyons coinciding with the alignment of the Cristianitos fault. Rocks within and around the fault tend to be fractured, jointed and otherwise weakened, to allow slump type failures in the bedrock. Outside of the areas underlain by rock disturbed by the faults, the sliding usually occurs in the soft formations where oversteepening of the canyon walls will permit a slump in the weak rocks. Some sliding, especially in the Capistrano Formation, may be due to unsupported bedding planes.

Along the coast a series of large slides is located about a mile south of San Onofre Nuclear Generating Plant No. 1. One of these slides coincides with the coastal exposure of the Cristianitos fault. All of the slides appear to have occurred in the Capistrano Formation. The investigation of these landslides was beyond the scope of this report.

4.2.7 Alluvium, Slopewash, Fan and Beach Deposits

The alluvium occurs chiefly as thick deposits of silt, sand, gravel, cobbles and boulders in the channels of San Onofre and San Mateo Canyons. The fan deposits have a similar composition but merge into the main drainage courses from the mouths of tributary streams.

Slopewash debris represents thick accumulations of soil (silt, sand, and gravel) in the broad swales. These deposits are generally porous and of low density.

Beach deposits consist of wave deposited sand and gravel along the coastal strand between the cliffs and ocean. These deposits merge with the alluvium of San Mateo and San Onofre Creeks.

4.3 Structure

4.3.1 Stratification and Folds

The stratification of the Miocene and Pleistocene rocks is gently undulatory west of the Cristianitos fault. Near the north end of the area mapped, bedding in the Capistano Formation dips 10 degrees northeast near the Cristianitos fault, and becomes horizontal and west dipping to form a broad east-west trending fold along the west side of San Mateo Creek. Bedding north of the San Clemente Golf Course dips from 16 degrees southeast to 5 degrees northwest. Other published maps in the San Clemente area confirm that the Capistrano Formation is gently folded north of the site. The stratification of the Capistrano Formation exposed in the San Onofre Bluff excavation is sheared and tightly folded. The shears trend north-south and the folds trend east-west.

The stratification of the San Mateo Formation generally inclines 3 to 16 degrees to the northwest with some horizontal bedding exposed along the coast. The bedding exposed along the north point of the gravel pit (San Mateo Canyon) dips 22 to 25 degrees south, indicating a pronounced change in attitude near the Cristianitos fault. This may not necessarily be due to tectonic movement since the San Mateo Formation unconformably overlies the Capistrano Formation and is erractically distributed. In addition, the point could represent a preexisting barrier against which the San Mateo Formation was deposited.

The San Onofre Formation east of the Cristianitos fault dips 42 degrees to the southwest. The breccia and conglomerate was poorly exposed and appear massive in most outcrops.

The Santiago Formation was not sufficiently exposed to determine the attitude of stratification.

4.3.2 Faults

The Cristianitos fault is the major structural feature in the area mapped. The fault intersects the coast about 4800 feet south of San Onofre Unit No. 1 and trends inland approximately north 20 degrees west for about 20 miles. In the mapped area, the Cristianitos fault juxtaposes Eocene and Middle Miocene rocks, Santiago and San Onofre Formations, respectively, against Upper Miocene Capistrano and Plio-Pleistocene (?) San Mateo Formations. Various published and unpublished geologic data have indicated that the Cristianitos fault is essentially a single trace between San Mateo Canyon and the coast, and branches into several subparallel traces north of San Mateo Canyon.

The traces of the Cristianitos fault are generally not well defined by the topography, but the general trend is inferred from: (1) the prominent ridge projecting at about north 20 degrees west into the bend of San Mateo Creek; (2) the long, relatively straight alignment of a large tributary canyon into San Onofre Creek; and (3) a series of aligned, north-trending swales inland from the coastal exposure of the Cristianitos fault. With the exception of this coastal exposure, the traces of the fault were not observed in natural outcrops.

Lithologic changes provided much of the evidence for mapping two distinct traces of the Cristianitos fault. The east trace defines the boundary between the older rocks (Eocene and Middle Miocene) and the younger rocks (Upper Miocene to Plio-Pleistocene). Lithologic changes usually produced slight changes in the topography which also assisted in accurately locating the east trace. The Basilone Road cut about 1-1/2 miles north of Coast Highway truncates two knobs separated by a small swale. The east cut exposes San Onofre Formation and the west cut consists of contorted Capistrano shale, indicating the fault, at that point, passes through the swale. Near the coast, the east trace is defined by the topographic change from the rugged San Onofre Mountains to the rolling foothills, which represents the change from San Onofre Formation to San Mateo Formation.

Detailed geologic mapping at the gravel-pit ridge (projecting into San Mateo Creek), and several canyons along the 4-1/2 miles of the fault suggests that a second trace also exists. This trace parallels the east fault and is on the order of 200 to 800 feet west. At the gravel-pit ridge, a small notch in the crest corresponds to a juxtaposition of San Mateo sandstone against San Onofre (?) conglomerate. On the opposite side of the ridge, the San Mateo sandstone makes a subtle color and lithologic change within the width of a small, northwest-trending canyon.

In a west-draining canyon with steep, well exposed walls, a color change was noted in the San Mateo sandstone. This color change occurred about 700 feet west of the east trace along a zone of vegetation about three to four feet wide dipping 72 degrees southwest. The fault surface was not exposed but the inferred strike was about north 30 degrees west.

Along the foothills of the San Onofre Mountains near the coast, a series of aligned, north-trending swales revealed San Mateo sandstone with prominent joints. These joints project from the sandstone as planar ribs, apparently due to cementation and differential erosion. These joints trend 5 to 20 degrees east and generally dip 60 to 75 degrees northwest. A slight color, lithologic and topographic change in the sandstone occurs within the width of one of these swales, further suggesting that a west trace passes through this area. At this point the traces are inferred to trend approximately north-south and are about 250 feet apart.

In the San Onofre Bluff excavation, a sharp fault contact at Station 0+00 (see Figure 8) separates the San Mateo sandstone on the north from the Capistrano shale. The fault strikes north 20 to 48 degrees east and dips 54 degrees northwest. Gouge

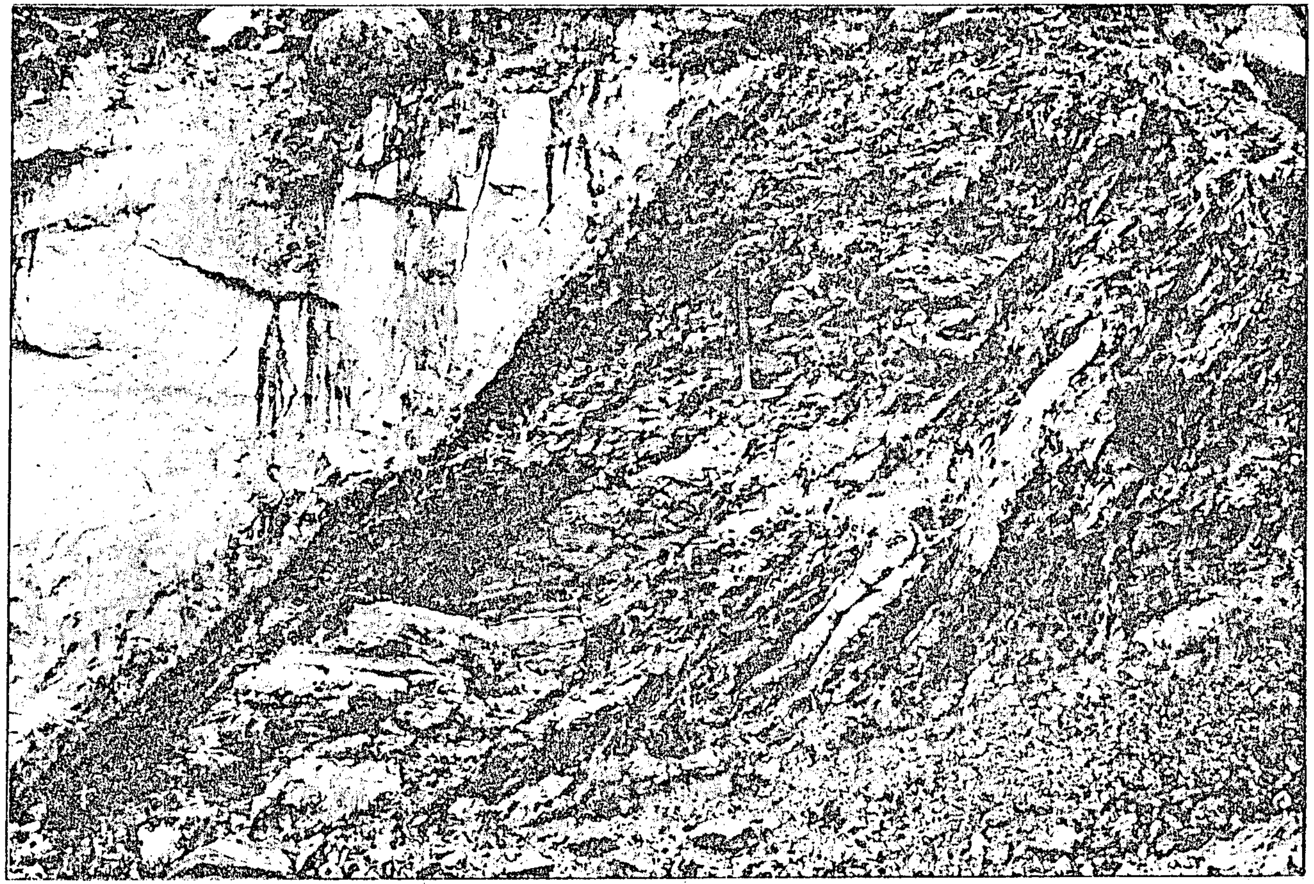


Figure 8

A portion of the San Onofre Bluffs excavation between Stations 0 and 8 showing the light brown San Mateo sandstone (left) juxtaposed against the dark gray clayey siltstone of the Capistrano Formation. The contact between terrace materials and bedrock (near the top of the photo) is not displaced.

varies in thickness from less than an inch near the bottom of the excavation to several inches near the terrace contact. A number of shears are evident for a considerable distance to each side of the fault, but a concentration was mapped from Stations 1+06 to 2+50. These shears trend about north-south and dip from 50 to 75 degrees to the east and west. The lateral separation between this concentration of shears and the large fault normal to the trend is about 210 feet. The number, spacing, and orientation of the shears exposed along the coast seems to closely correspond with the inferred geologic data from field mapping.

In summary, the mapping of approximately 4.5 miles of the Cristianitos fault between San Mateo Canyon and the coast indicated that the fault consists of two parallel traces 200 to 800 feet apart. The zone between the traces was found to be contorted in some instances, but where observed, was not crushed and did not represent a gouge zone. The average orientation of the Cristianitos fault in the mapped area was about north 20 degrees west, in general agreement with the overall trend. Near the coast the orientation changes to nearly north-south. The dip of the fault at the San Onofre Bluff excavation is 54 degrees west and is inferred from the geologic mapping to be 60 to 75 degrees west farther inland.

The shear surfaces exposed in the San Onofre Bluffs excavation and in the Plano Trabuco excavation did not extend into the overlying terrace deposits. Due to lack of organic debris, radiometric dates in the San Onofre Bluffs excavation could not be determined. However, based upon Radiometric C14 dating by Geochron Laboratories, Inc., on shell fragments taken from the base of the terrace deposits at the seacliff 4.5 miles south of the plant site, the age of the terrace is greater than 33,000 years. Similarly, an age dating of the undisrupted terrace overlying an element of the Cristianitos fault in the Plano Trabuco excavation, see Appendix D, indicates an age greater than 32,600 years, at a point at least 20 feet above the base of the terrace.

Age dating of marine terraces along the coast between Palos Verdes and Oceanside indicate the 75-foot elevation terrace to be about 80,000 years old. The 75-foot elevation represents the elevation at the shoreline angle or the intercept of the terrace platform with the riser sloper. Correlations of marine terraces along the coast by Palmer (1967) indicate that southeast of the Newport-Inglewood fault there is remarkable continuity to the terraces, suggesting long-term tectonic stability.

Another fault was mapped along the west side of San Mateo Creek near the intersection with Cristianitos Creek. This fault is covered by slump debris but is inferred to separate Capistrano Formation from San Mateo Formation. The fault is estimated to trend north 65 degrees west, apparently intersecting the Cristianitos fault near the gravel-pit ridge.

No other faults were mapped in the area nor was there any evidence of faults projecting toward the site.

REFERENCES

1. Albee, A.L. and Smith, J.L., 1966, Earthquake Characteristics and Fault Activity in Southern California: Special Publication of the Association of Engineering Geologists, "Engineering Geology in Southern California," October 1966, pp. 9-33.

2. Albee, A.L. and Smith, J.L., 1967, Geologic Site Criteria for Nuclear Power Plant Location: Society of Mining Engineers Transactions, December 1967, pp. 430-434.

3. Allen, C.R., St. Amand, P., Richter, C.F. and Nordquist, J.M., 1965, Relationship Between Seismicity and Geologic Structure in the Southern California Region: Bull. Seis. Soc. of America, Vol. 55, No. 4, August 1965, pp. 753-797.

4. Ball, A.R., 1961, Geology of the Northern and Western Parts of the San Clemente Quandrangle, Orange County, California, U.S.C. M.A. Thesis (Unpublished), 68 p.

5. Bechtel, 1967, Detailed Investigation of Bolsa Island Site.

6. California Department of Water Resources, 1964a, Crustal Strain and Fault Movement Investigation: California Dept. of Water Resources Bull. 116-2, 96 p.

7. California Division of Water Resources, 1956, Santa Margarita River Investigation: Bull. No. 57.

8. Carson, M.V.,III, 1967, Geology of the Santiago Peak Quadrangle, Orange and Riverside Counties, California, U.S.C. M.S. Thesis (Unpublished) 85 p.

9. Cleveland, G.B. and Blanc, R.P., 1968, Slope Stability Related to Geology, San Clemente Area, Orange and San Diego Counties, California: California Division of Mines and Geology, Special Report 98.

10. Duggan, M.D., 1961, Geology of a Part of the San Joaquin Hills, Orange County, California. U.C.L.A. M.A. Thesis (Unpublished) 81 p.

11. Ellis, A.J. and Lee, C.H., 1919, Geology and Ground Waters of the Western Part of San Diego County, California: U.S.G.S. Water Supply Paper 446.

12. Emery, K.O., 1960, The Sea off Southern California: John Wiley and Sons, New York, 366 p.

13. Emery, K.O. and Bray, E.E., 1962, Radiocarbon Dating of California Basin Sediments: Amer. Assoc. Petroleum Geologists Bull., Vol. 46, No. 10, pp. 1839-1856.

References (Continued)

14. Engle, R., 1959, Geology of the Lake Elsinore Quadrangle, California, California Division of Mines Bull. 146.

15. Fernandez, A.P., 1959, Geology of a Portion of the Capistrano Basin, California, U.C.L.A. M.A. Thesis (Unpublished) 83. p.

16. Goodban, F.R., 1959, San Clemente Oil Field, "Guide to the Geology and Oil Fields of the Los Angeles and Ventura Regions," Pacific Section, Amer. Assoc. Petroleum Geologists, Annual Meeting, pp. 145-148.

17. Gray, C.H.,Jr., 1961, Geology of the Corona South Quadrangle and the Santa Ana Narrows Areas, Riverside, Orange and San Bernardino Counties, California: California Div. of Mines Bull. 178.

18. Jahns, R.H., 1954, Geology of the Peninsular Range Province, Southern California and Baja California, California Division of Mines Bull. 170.

19. Ingue, J.C.,Jr., 1962, Paleoecologic, Sedimentary, and Structural History of the Late Tertiary Capistrano Embayment, California, U.S.C. M.S. Thesis (Unpublished) 166 p.

20. Killen, J.L., 1961, Geology of a Part of the San Joaquin Hills, Orange County, California, U.C.L.A. M.A. Thesis (Unpublished) 81 p.

21. Lamar, D.L., 1959, Geology of the Corona Area, Orange, Riverside and San Bernardino Counties, California, U.C.L.A. M.A. Thesis (Unpublished) 95 p.

22. Larson, E.S.,Jr., 1948, Batholith and Associated Rocks of Corona, Elsinore, and San Luis Rey Quandrangles, Southern California: Geological Society of America, Memoir 29.

23. Levet, M.N., 1940, Geology of the San Juan Canyon Area, Orange County, California: California Institute of Technology M.S. Thesis (Unpublished) 42 p.

24. Lewis, L.A., 1941, Geology of the Northern Part of the Santa Ana Mountains, Orange County, California: California Institute of Technology M.S. Thesis (Unpublished) 66 p.

References (Continued)

25. Mann, J.F., Jr., 1955, Geology of a Portion of the Elsinore Fault Zone, California: California Division of Mines, Special Report 43.

26. McCulloh, T.H., 1960, Gravity Variations and the Geology of the Los Angeles Basin of California: U.S.G.S. Prof. Paper 400-B.

27. Moore, B.N., 1930, Geology of the Southern Santa Ana Mountains, Orange County, California: California Institute of Technology, Ph.D. Thesis (Unpublished) 135 p.

28. Oates, N.D., 1960, Geology of the Western Portion of the Canada Gobernadora Quadrangle, Orange County, California: U.S.C. M.A. Thesis (Unpublished) 98 p.

29. Palmer, L.A., 1967, Marine Terraces of California, Oregon and Washington: U.C.L.A. Ph.D. Thesis (Unpublished) 379 p.

30. Richmond, J.F., 1952, Geology of Burruel Ridge, Northwestern Santa Ana Mountains, California: California Division of Mines and Geol., Special Report 21.

31. Richter, C.F., 1958, Elementary Seismology: W. H. Freeman and Company, San Francisco, 768 p.

32. Roth, J.C., 1958, Geology of a Portion of the Southern Santa Ana Mountains, Orange County, California: U.C.L.A. M.A. Thesis (Unpublished) 93 p.

33. Shepard, F.P. and Emery, K.O., 1941, Submarine Topography of the Southern California Coast: Canyons and Tectonic Interpretation: Geological Society of America, Special Paper 31.

34. Smith, P.B., 1960, Foraminifera of the Monterey Shale and Puente Formation, Santa Ana Mountains and San Juan Capistrano Area, California: U.S.G.S. Prof. Paper 294M.

35. Southwick, T.S., 1928, Geology of a Portion of the Santa Ana Mountains, California: California Institute of Technology, M.S. Thesis (Unpublished) 45 p.

36. Stevenson, R.E., 1948, The Cretaceous Stratigraphy of the Southern Santa Ana Mountains, California: U.C.L.A. M.A. Thesis (Unpublished) 37 p.

References (Continued)

37. Weber, F.H., Jr., 1963, Geology and Mineral Resources of San Diego County, California: California Division of Mines and Geol., County Report 3.

38. Woodford, A.O., 1925, The San Onofre Breccia, Its Nature and Origin: University of California, Department of Geol. Sci. Bull., Vol. 15, No. 7, pp. 159-280.

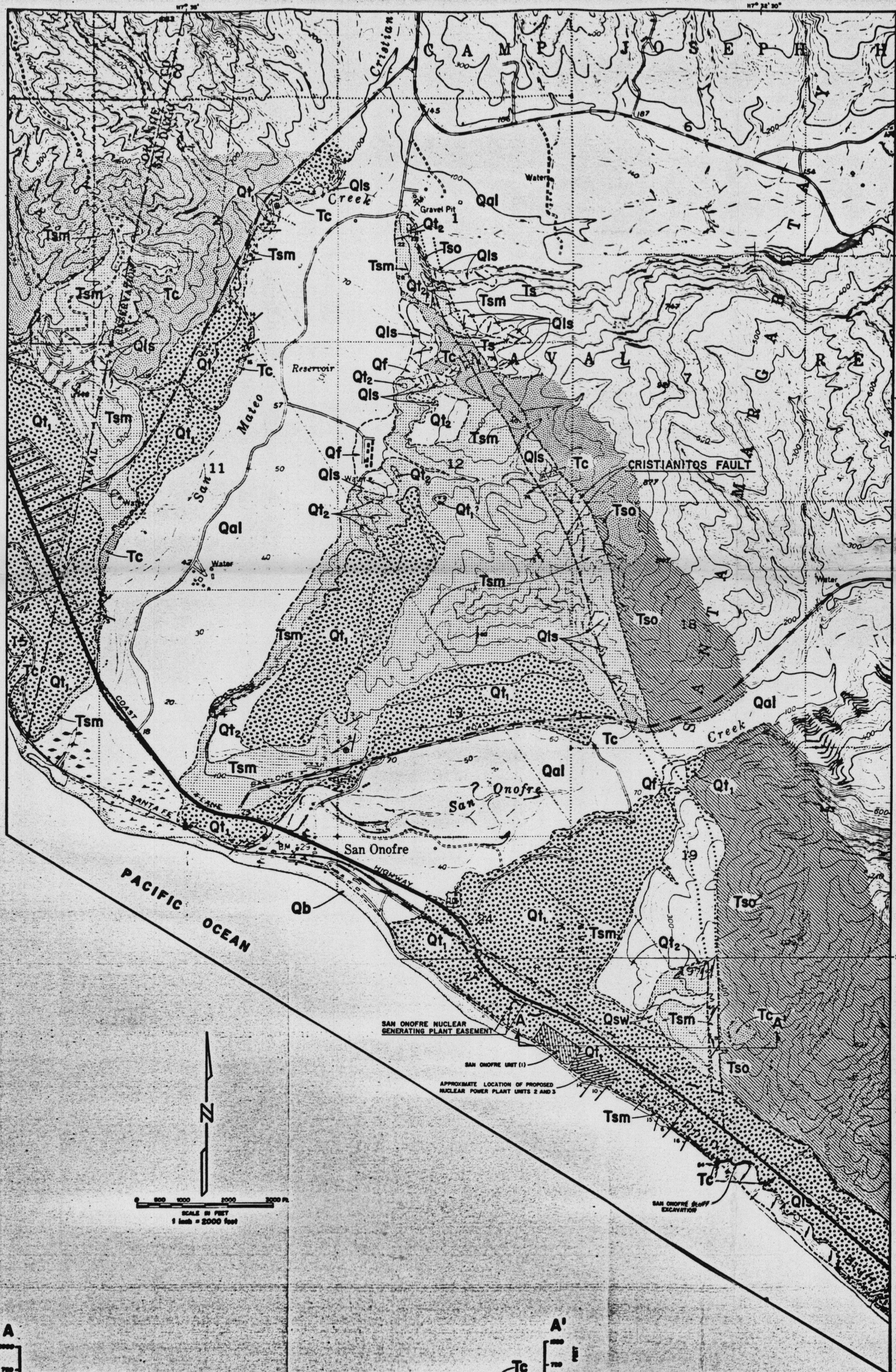
39. Woodford, A.O., Schoellhamer, J.E., Vedder, J.G., Yerkes, R.F., 1954, Geology of the Los Angeles Basin: California Div. of Mines Bull. 170.

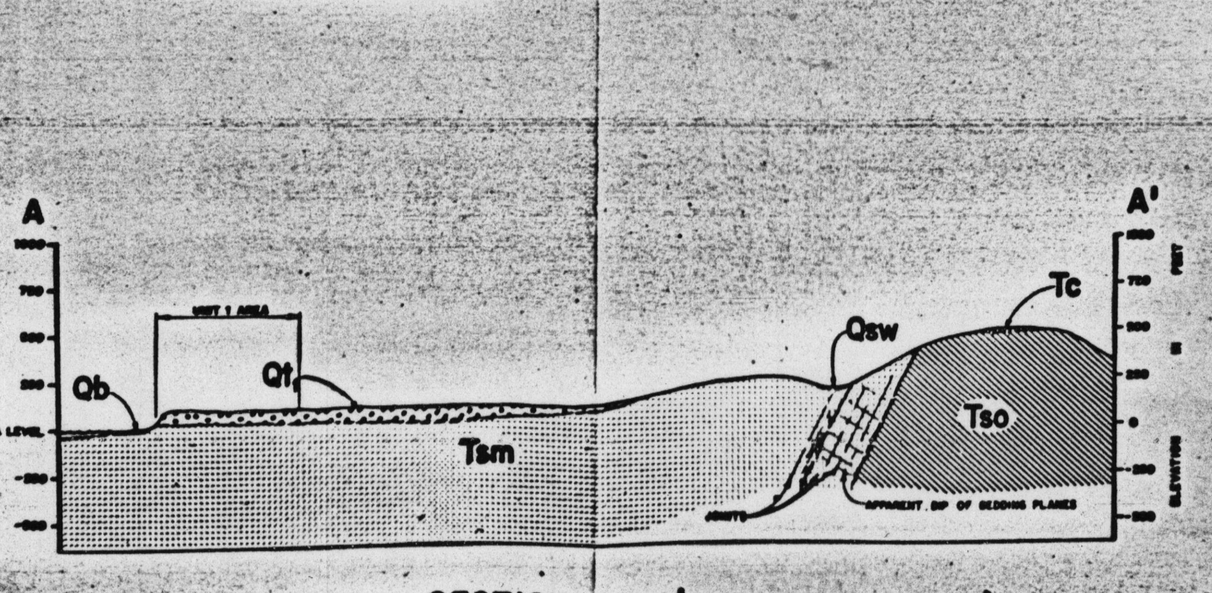
40. Yerkes, R.F., 1957, Volcanic Rocks of the El Modeno Area, Orange County, California: U.S.G.S., Prof. Paper 274L.

41. Yerkes, R.F., McCulloh, T.H., Schoellhamer, J.E. and Vedder, J.G., 1965, Geology of the Los Angeles Basin, California; An Introduction: U.S.G.S., Prof. Paper 420A.

APPENDIX A

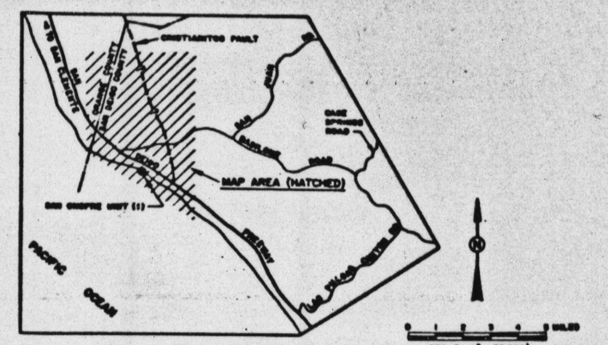
GEOLOGIC MAP & SECTION			
PREPARED BY: J.D.S., R.N., G.T.	PROPOSED SAN ONOFRE NUCLEAR POWER PLANT UNITS 2 AND 3 for Southern California Edison		DRAWING NO. 1
CHECKED BY: T.T.			
APPROVED BY: R.Q.S.	DATE: Mar. 24, 1970	SCALE: As Shown	PROJECT NO. 70-034-H
CONVERSE, DAVIS AND ASSOCIATES	PASADENA • SANTA ANA, CALIFORNIA		





SECTION A-A'

1" = 1000'



AREA MAP

EXPLANATION

QUATERNARY

Symbol	Description
Qb	Beach Deposits - sand, gravel and cobbles.
Qsw	Slopewash Debris - soil and creep affected bedrock where estimated to be 5 feet or more thick.
Qal	Alluvium - silt, sand, gravel, cobbles and boulders.
Qf	Fan Deposits - silt, sand, gravel and cobbles.
Qls	Landslide
Qt_1	Non-Marine Terrace Deposits - brown gray to dark brown, silt and fine to coarse grain sand with thick layers of gravel and cobbles. Along the flood plains of the major drainage courses a brown gray silty sand, fine to coarse grained; where estimated to be 5 feet or more thick. Marine (?) Terrace locally exposed in lower 5± feet of coastal section
Qt_2	Non-Marine Terrace Deposits - rounded gravel and cobbles in red brown silty sand matrix where estimated to be 5 feet or more thick.

BEDROCK

TERTIARY

Age	Symbol	Description
PLIOCENE TO PLEISTOCENE	Tsm	San Mateo Formation - light brown and light gray arkosic Sandstone, massive to thickly bedded, well consolidated, local outcrops of gray cobble conglomerate derived from San Onofre Formation and light gray green Siltstone.
	UNCONFORMITY	
UPPER MIOCENE	Tc	Capistrano Formation - dark gray and light gray Siltstone and clayey Siltstone with scattered interbedded layers of Sandstone, tuff and diatomite.
	UNCONFORMITY	
MIDDLE TO UPPER MIOCENE	Tso	San Onofre Formation - dark gray and brown gray breccia and conglomerate characterized by clasts of blue green glaucophane schist. Local outcrops of gray brown medium to coarse grain Sandstone.
	UNCONFORMITY	
EOCENE	Ts	Santiago Formation - gray massive arkosic Sandstone, uncemented

SYMBOLS

- Geologic contact - dashed where approximately located, dotted where concealed, questioned where location uncertain.
- Fault - arrow indicates direction of dip. Fault dashed where inferred, dotted where concealed, questioned where location uncertain
- Strike and dip of bedding planes
- Horizontal bedding
- Strike and dip of inferred bedding planes
- Strike and dip of shear surface
- Strike and dip of joint plane
- Location of exploratory trench
- Landslide, questioned where uncertain
- Anticline

NOTE: AREAS TO THE NORTH AND NORTHEAST OF THE CRISTIANITOS FAULT WERE NOT MAPPED DUE TO RESTRICTED ACCESS.

TOPOGRAPHIC REFERENCE: San Onofre Bluffs Quadrangle, 7.5 Minute Series, United States Geological Survey.

APPENDIX B

SAN ONOFRE BLUFF EXCAVATION
STATIONS 0+00 to 6+80

APPENDIX B

SAN ONOFRE BLUFF EXCAVATION
STATIONS 0+00 to 6+80

1. INVESTIGATION METHODS

A trench was excavated along the base of the seacliff about 4000 feet south of Unit 1 where an element of the Cristianitos fault is exposed. The excavation was stationed in feet along the arcuate plan outline of the toe of the cliff face for a distance of 680 feet. The trench as positioned nearly at right angles to the trend of presumed faults and was extended as far a practical. A transit was used to accurately determine lines of equal elevation along the trench wall.

The trench was carefully examined after scraping the walls to remove any caked or smeared soil. Significant geologic details on the fresh surfaces were then marked with nails to preserve their position and facilitate accurate logging. The trench logs are presented on Drawing Nos. 2 through 5.

2. LITHOLOGY

2.1 Capistrano Formation

The Capistrano Formation forms the sedimentary bedrock platform exposed from Stations 0+00 to 6+80. This rock unit consists predominantly of laminated clayey siltstone and thinly bedded siltstone. The freshly exposed rock varies in color from dark brown to gray-brown and dark gray, and ranges in consistency from soft to hard. Fractures are generally spaced from less than one inch to several inches apart, and form hackly to blocky fragments.

Bedrock in and adjacent to the more structurally complex areas of the trench generally (1) displays marked fissility along bedding, (2) is relatively soft, (3) contains seeps or moist areas, and (4) is intensely fractured. The fractured rock in these areas breaks into prismatic fragments with smooth, commonly shiny parting surfaces, which occur predominantly in the more clayey portions of the bedrock.

Other minor rock types occur as lenses, seams and thin interbeds. In order of decreasing abundance, these rocks consist of very fine grained, light gray sandstone, tuff, diatomite and bentonitic tuff. These materials rarely exceed six inches in thickness and comprise a small percentage of the total bedrock exposed in the trench. The formation weathers at the top of the bedrock platform to a distinct, soft, green-gray to blue-gray claystone a few inches in thickness.

Fossils encountered in the formation include several large ribs, vertebra and other skeletal remains at Station 1+02. These bones were soft, deeply weathered and crumbled during extraction from the trench wall. A shark tooth was recovered from the weathered bedrock zone at Station 3+74. Reddish-brown fish scales can be found throughout the formation.

2.2 <u>San Mateo Formation</u>

The San Mateo Formation forms the bedrock platform from Station 0+00 northwestward along the sea coast for a distance of about three miles. This rock consists of poorly cemented, massive, fine to coarse-grained, cross laminated, yellow-brown sandstone. Minor, discontinuous layers of thinly bedded silty sandstone and sandy siltstone occur at widely spaced intervals along the seacliff. Rock fragments and pebbles to about one inch in diameter are scattered throughout the sandstone, commonly oriented with their longest dimension parallel with bedding. Angular blocks and slabs of gray-green, micaceous silty sandstone up to nine feet long and three feet thick are embedded in the sandstone.

Generally the formation appears indistinctly bedded, however, upon close examination the coarser sand grains, rock fragments and small pebbles maintain a preferred orientation compatible with more clearly defined bedding features. Bedding orientations generally strike northeast-southwest and dip about five to ten degrees northwestward, or landward. Exceptions to this orientation occur near the faults and fractures adjacent to Station 0+00.

2.3 Terrace Deposits

Pleistocene marine erosion has cut a gently sloping bench into the bedrock along the sea coast, both north and south of Unit 1. Crudely statified, cohesionless terrace deposits overly these benches and vary from 30 to about 50 feet in thickness between Unit 1 and the exploratory trench to the southeast. At the base of these deposits along the beach front, and resting directly on the bedrock, is a two to five-foot thick cobble and boulder layer in a coarse sand matrix. This deposit is overlain by brown to gray-brown mixtures of sand, silt and clay with scattered lenses and pockets of gravel and cobbles.

Inland from the beach the exploratory trench exposes terrace deposits underlying the cobble and boulder layer. These deposits consist of interfingering light gray to light brown, cross-bedded, fine to coarse-grained sands, gravels and boulders dipping seaward about six to eight degrees. Some beds are traceable for up to 100 feet or more. Orange oxide stains commonly occur throughout the sands and gravels, particularly near the bedrock contact. The stains form irregular patches and streaks roughly parallel with the sense of layering. Although no shells were found in these deposits, marine mollusks were recovered from similar deposits 3.5± miles to the southeast of the excavation.

3. STRUCTURE

Stratification, folds, joints and shears are the principal structural features of the bedrock exposed in the excavation. Stratification and many minor discontinuities and contortions within the bedrock are primary features formed simultaneously with or shortly after deposition of the sediments. These features are distinguished from the broader folds, shears and joints, many of which are secondary features produced by tectonic forces acting on the rocks after lithification. Primary sedimentary features occur throughout the bedrock, whereas the greatest concentration of tectonic-related features occurs between Stations 0+00 and 2+50. Detailed mapping revealed no shears or displacements in the sand or gravel beds of the terrace deposits overlying the bedrock.

3.1 <u>Stations 0+00 to 2+50</u>

A sharp shear contact at Station 0+00 separates the San Mateo sandstone on the north from the Capistrano shale exposed in the trench. The shear strikes north 20 to 48 degrees east and dips to the northwest at 54 degrees. The bedrock between Stations 0+00 and 0+40 is highly contorted and contains closely spaced shears. The shear surfaces consist of planar breaks separating dissimilar bedding attitudes, rock consistencies, or lithologic units with various magnitudes of apparent displacement. Small-scale drag folds and thin clay seams are associated with some shears. Commonly, shear surfaces can be traced nearly parallel with stratification, then cut across beds, and follow a new set of strata. Breaks in the bedrock exhibiting any or all of these features have been designated as shears.

Between Stations 0+40 and 1+06, stratification is virtually unbroken and dips consistently westward. At Stations 1+06 to 2+50, the bedrock consists of blocks with dissimilar orientations bounded by shear surfaces. The strata within the individual blocks are folded, display shiny parting surfaces and contain seeps of up to about 1/4 gallon per minute. The shears mapped within Stations 0+00 to 0+40 and 1+06 to 2+50 generally coincide with either of two sets of intersecting orientations. One set of shears strikes nearly due north-south, the other strikes about north 30 degrees east. Both shear sets dip generally to the west or northwest about 50 to 75 degrees. These orientations are more or less consistent with the orientation of the shear at Station 0+00 which separates the two formations.

3.2 Stations 2+50 to 6+70

The structural trend along this portion of the trench is nearly perpendicular to that described between Stations 0+00 to 2+50. Strata have been warped into broad folds which trend and plunge northwestward. Minor shears developed along the folds are imposed by very tight folding along the fold axes. The general trend of the strata is about east-west to north 70 degrees west with dips both to the north and south. Scattered shears occur along this portion of the trench although they are apparently not accompanied by any significant change of bedding orientation. Many examples of primary structural features occur such as intraformational corrugations, draped, warped and tightly folded bedding and low angle erosion surfaces. These features may be generally explained by movement of soft, semi-plastic sediment down a slightly inclined subaqueous slope during deposition. Stations 4+65 to 5+05 display some of these features, further complicated by minor subsequent shearing.

4. BEDROCK-TERRACE DEPOSIT CONTACT

The bedrock platform underlying the terrace deposits is generally flat and dips a few degrees seaward. Elevation of this bench varies no more than five feet in the 680-foot long excavation and has an approximate elevation of 55 feet. The elevation variations are due mostly to irregularities caused by differential erosion during or after development of the bench, but prior to deposition of the terrace deposits. The most irregular bedrock surface coincides with those portions of the trench that display the most tectonic features, namely, Stations 0+00 to 2+50. Understandably, the areas with the greatest number of shears will most commonly display juxtaposed rocks of dissimilar hardness. These areas exhibit differential erosion from fractions of an inch to one or two feet deep in the form of narrow troughs, potholes, undercut beds, depressions and highs of irregular shapes, see Figure 9.

At Stations 1+75 and 2+32, the bedrock surface appears to be offset in a vertical sense along bedrock shears for 6 inches and 1-1/2 inches, respectively. Despite detailed search, no evidence was found to suggest that the sand and gravel layers overlying these apparent offsets are either broken or offset, see Figure 10. Indeed, the continuity of the layers is remarkable as evidenced on the excavation logs, Drawing Nos. 2 through 5. These apparent offset features can be attributed either to differential erosion, settlement, or slight movements due to a number of causes along shear surfaces after erosion of the bedrock surface, but prior to deposition of the overlying terrace deposits.

5. SUMMARY

1. Two distinct zones of shear concentrations are recognizable, namely, from Stations 0+00 to 0+40 and from 1+06 to 2+50. The zone thus defined extends into the Capistrano Formation from the fault contact with the San Mateo sandstone for a distance of 200 feet, measured normal to the trend of faulting. Within this zone, a relatively unbroken block of bedrock occurs between Stations 0+40 and 1+06.

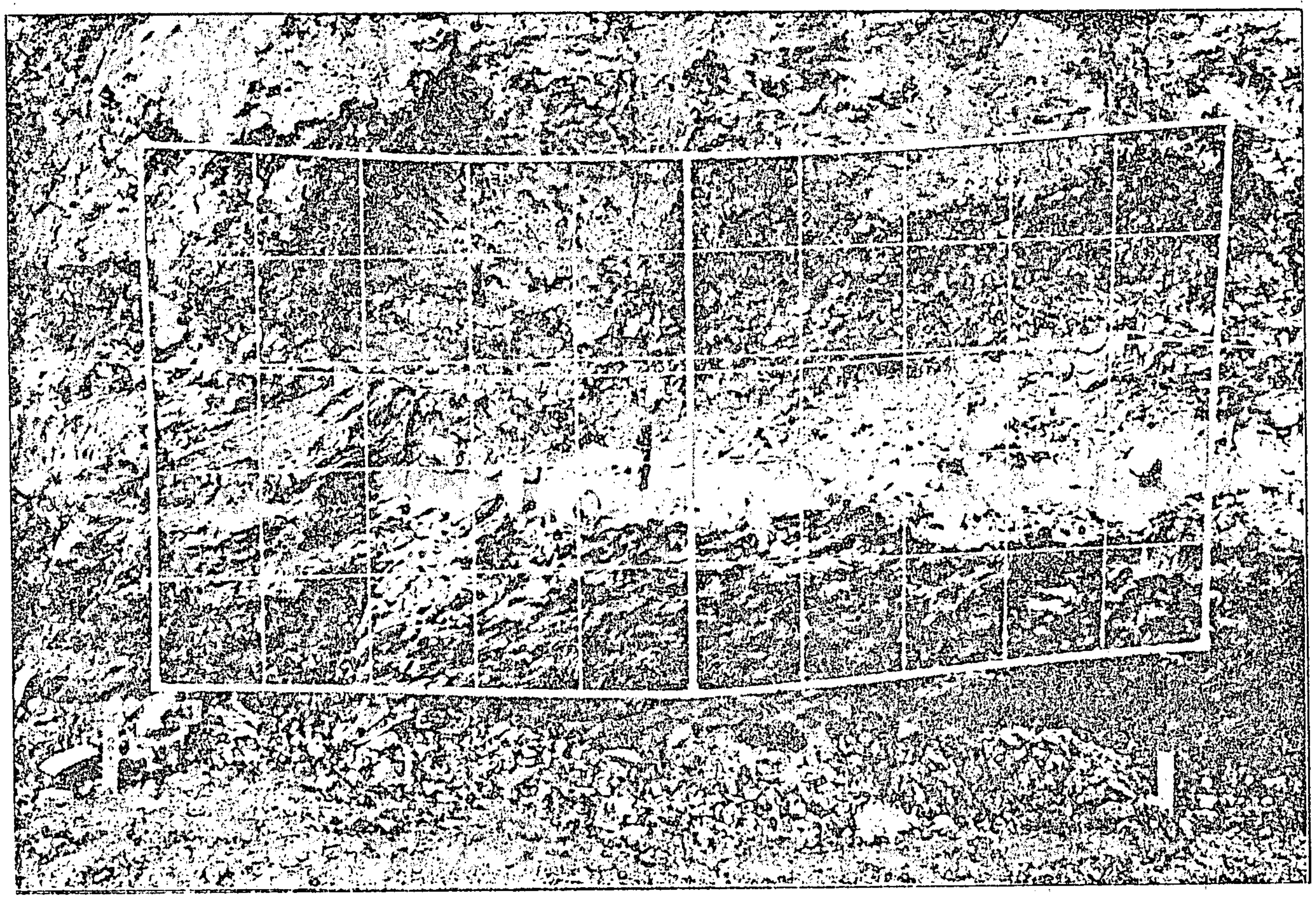
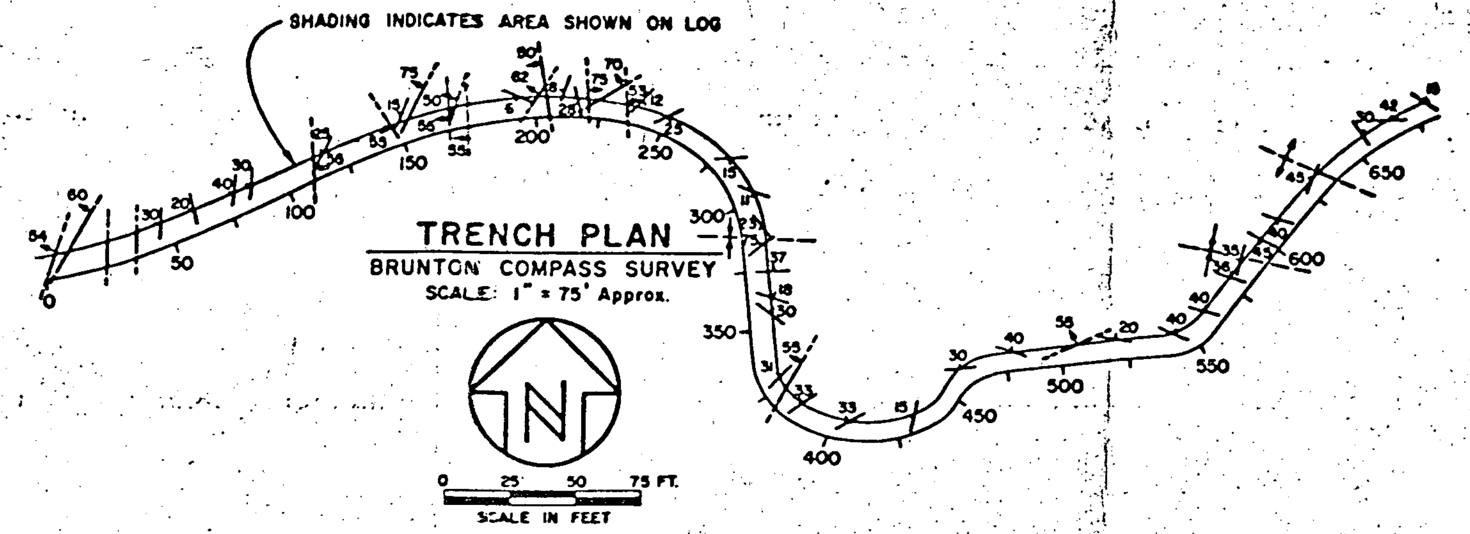


Figure 9

A portion of the San Onofre Bluffs excavation between Stations 98 and 112 (approximately) showing jog in the bedrock - terrace contact at Station 102. A large scale drawing of this feature is shown in the Detail Log of Drawing 2. The grid consists of a framework 5 feet high by 10 feet long with string at 1 foot intervals.

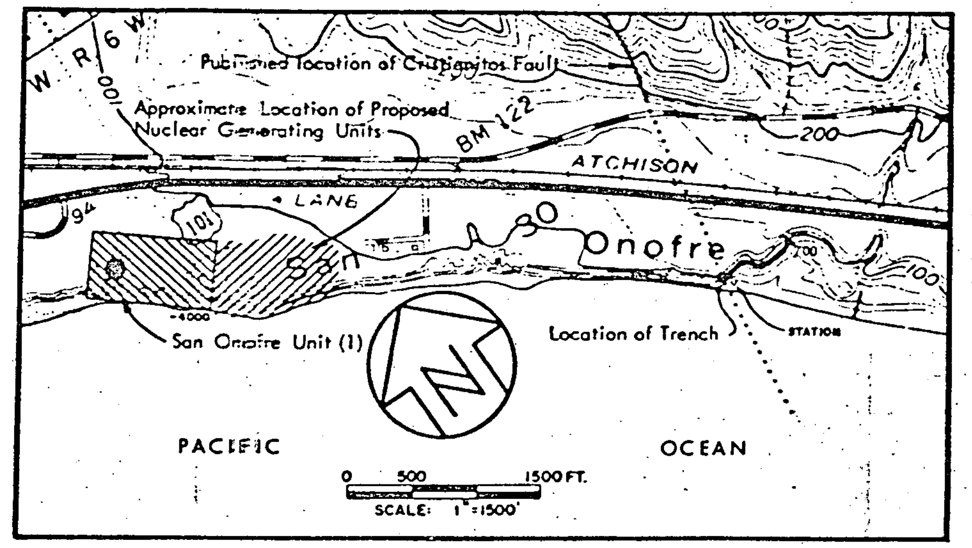
2. East of this zone, broad folds trend northwest-southeast with shears decreasing in number eastward.

3. Terrace deposits consisting of interlensing layers of sand and gravel mixtures overlie the bedrock formations on an elevated marine terrace. These deposits display unbroken and continuous laminations and layers which overlie the upward projections of the bedrock shears and fault. Apparent bedrock offsets of the marine platform occurred prior to deposition of the terrace materials and may be due to differential erosion or movement after formation of the terrace platform.

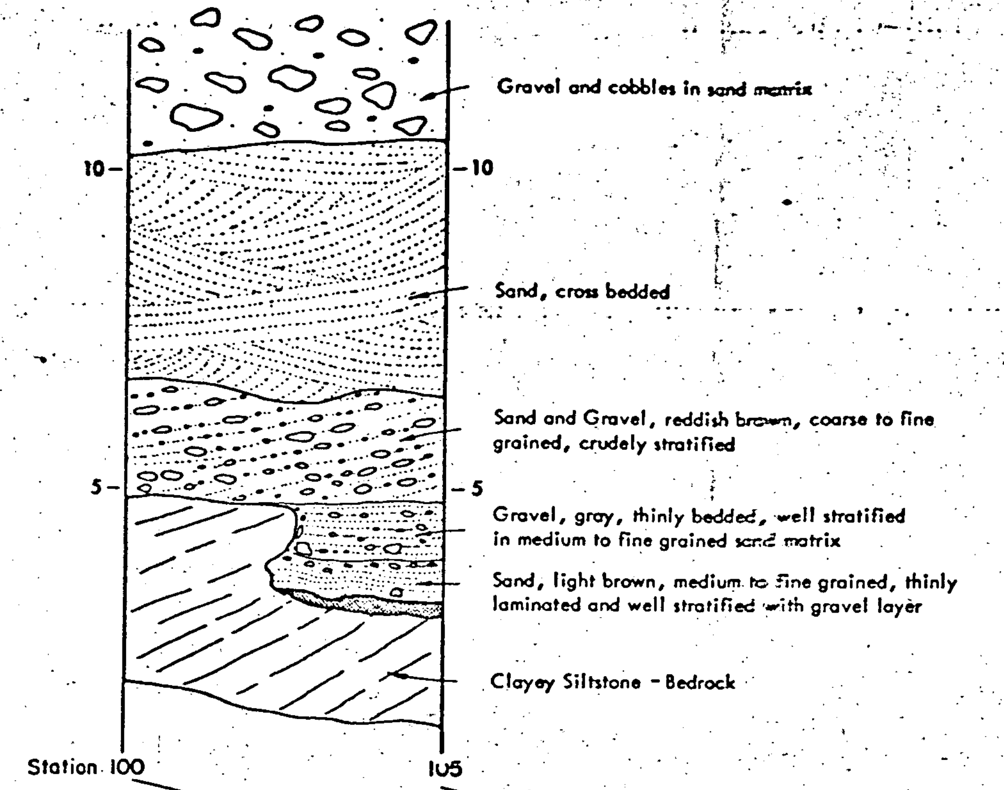


TRENCH PLAN
BRUNTON COMPASS SURVEY
SCALE: 1" = 75' Approx.

SCALE IN FEET



SCALE: 1" = 1500'



DETAIL LOG
SCALE: 1" = 3' Horizontal and Vertical

EXPLANATION

TERRACE

- Gravel and cobbles, gray to brown, in sand matrix, unstratified
- Sand and gravel, light gray, locally well stratified and laminated
- Sand, light gray to light brown, cross-bedded, thinly laminated with scattered lenses and stringers of gravel

BEDROCK

San Mateo Formation

- Sandstone, light brown to yellow brown

Capistrano Formation

- Clayey Siltstone, gray to dark gray, locally hackly with shiny parting surfaces; lines indicate apparent bedding orientations and emphasize displacements, weathered zone shown as dark stipling
- Clayey Siltstone, green, very contorted
- Silicified Sandstone or Siltstone concretion, brown to gray

NOTE:
Minor lithologic variations described on log

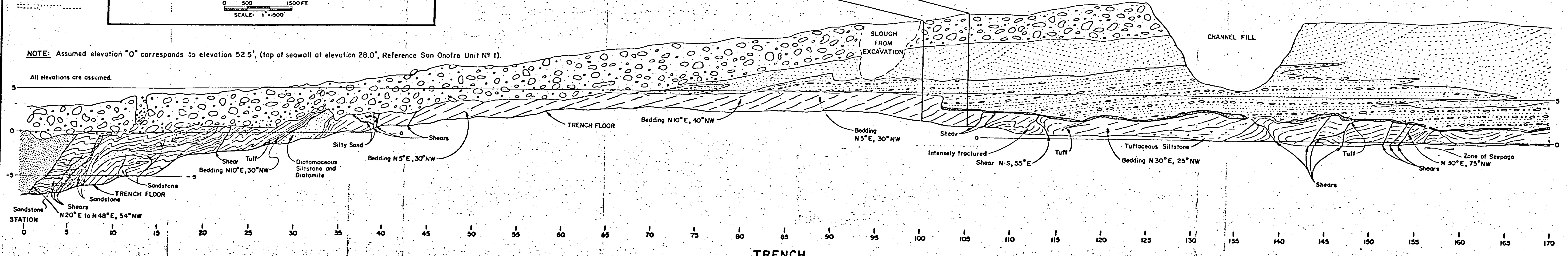
SYMBOLS

- Geologic contact
- Strike and dip of bedding plane showing amount of dip in degrees
- Strike and dip of shear surface showing amount of dip in degrees
- Syncline, showing trend and plunge direction of axis
- Anticline, showing trend of axis

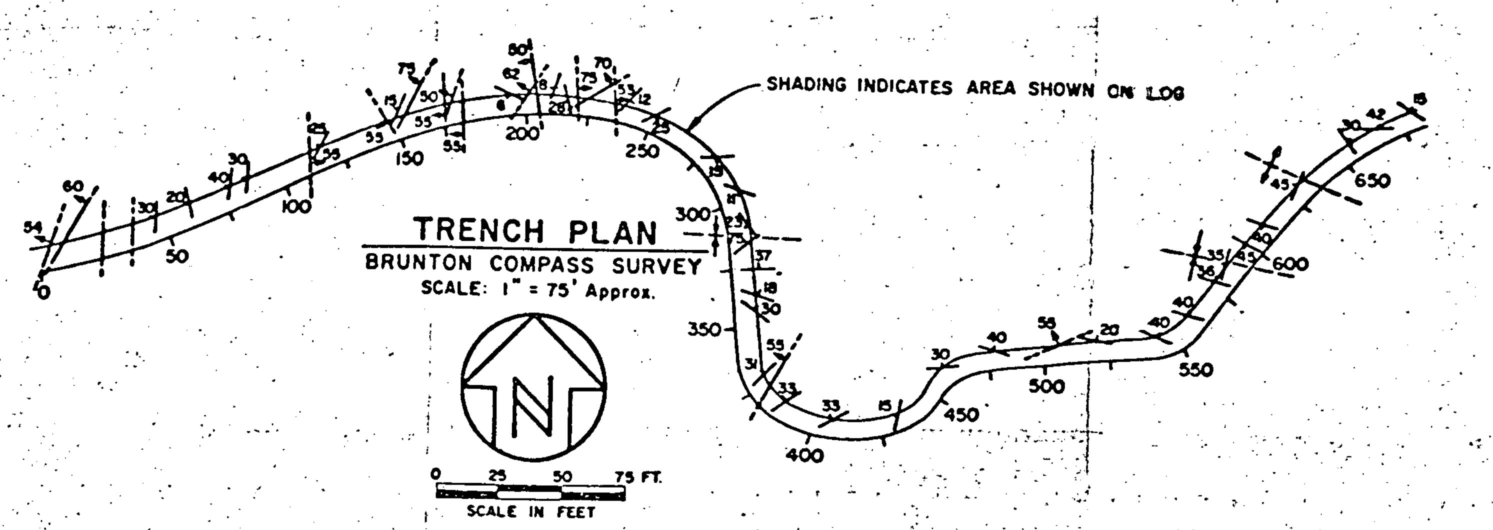
TRENCH LOG		
PREPARED BY: J.D.S. - G.D.T.	SAN ONOFRE BLUFF EXCAVATION for SOUTHERN CALIFORNIA EDISON COMPANY	DRAWING NO. 2
CHECKED BY: CTJS		
APPROVED BY: [signature]	DATE: APR. 13, 1970 · SCALE: As Shown · PROJECT NO. 70-034-H	
CONVERSE, DAVIS AND ASSOCIATES	PASADENA · SANTA ANA, CALIFORNIA	

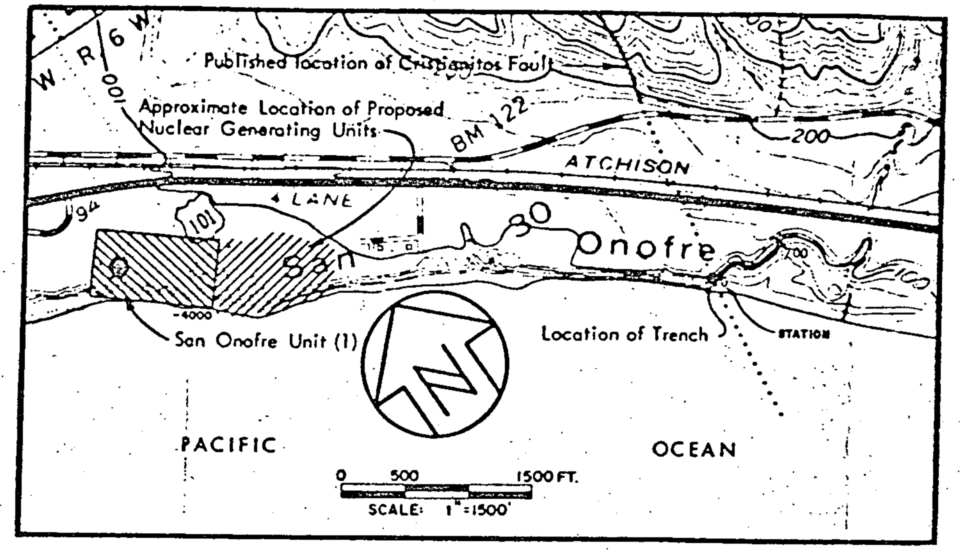
NOTE: Assumed elevation "0" corresponds to elevation 52.5', (top of seawall at elevation 28.0', Reference San Onofre Unit Nº 1).

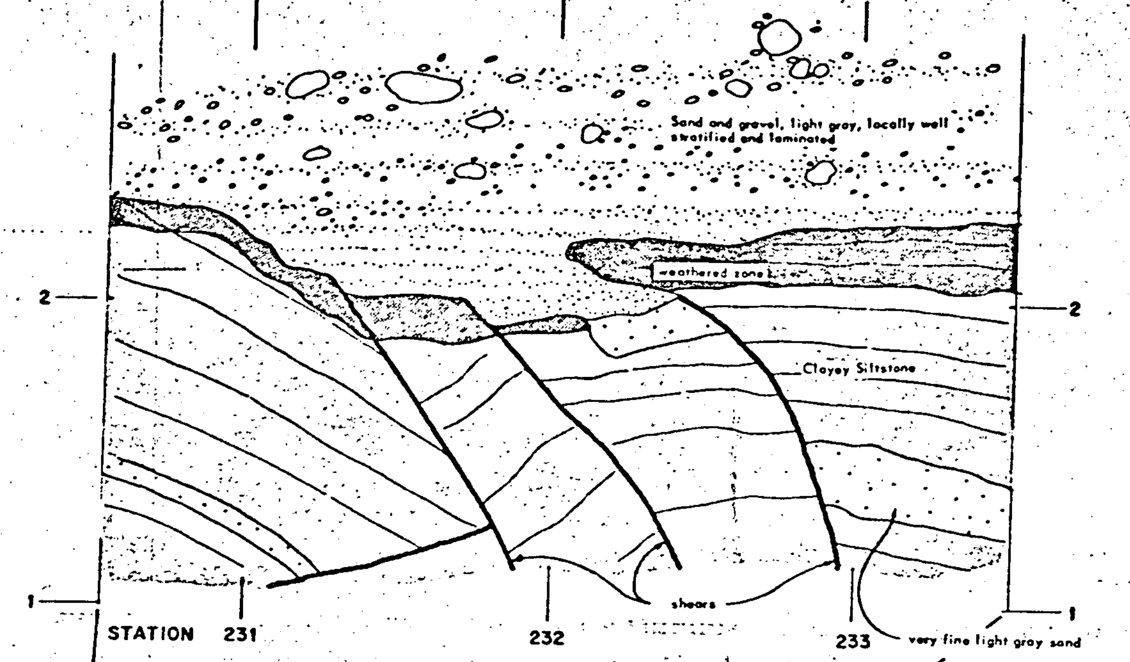
All elevations are assumed.



TRENCH
LOOKING NORTH
SCALE: 1" = 7.5' Horizontal and Vertical
0 7.5 15 Feet







DETAIL LOG
SCALE: 1" = 7.5' Horizontal and Vertical

EXPLANATION

TERRACE

- Gravel and cobbles, gray to brown, in sand matrix, unstratified
- Sand and gravel, light gray, locally well stratified and laminated
- Sand, light gray to light brown, cross-bedded, thinly laminated with scattered lenses and stringers of gravel

BEDROCK

San Mateo Formation

- Sandstone, light brown to yellow brown

Capistrano Formation

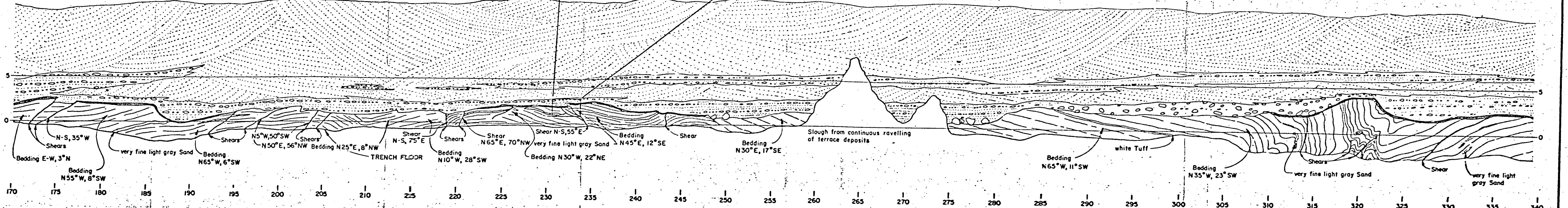
- Clayey Siltstone, gray to dark gray, locally hackly with shiny parting surfaces; lines indicate apparent bedding orientations and emphasize displacements, weathered zone shown as dark stipling
- Clayey Siltstone, green, very contorted
- Silicified Sandstone or Siltstone concretion, brown to gray

NOTE:
Minor lithologic variations described on log

SYMBOLS

- Geologic contact
- Strike and dip of bedding plane showing amount of dip in degrees
- Strike and dip of shear surface showing amount of dip in degrees
- Syncline, showing trend and plunge direction of axis
- Anticline, showing trend of axis

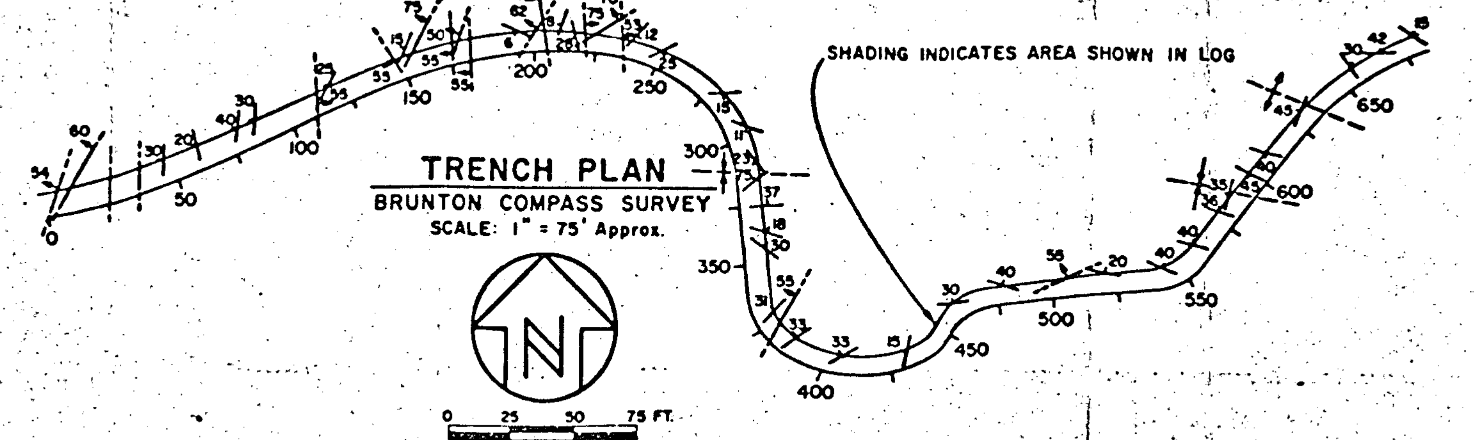
NOTE: Assumed elevation "0" corresponds to elevation 52.5', (top of seawall at elevation 28.0', Reference San Onofre Unit Nº 1).
All elevation are assumed



TRENCH
LOOKING NORTHEAST
SCALE: 1" = 7.5' Horizontal and Vertical
0 7.5 15 Feet

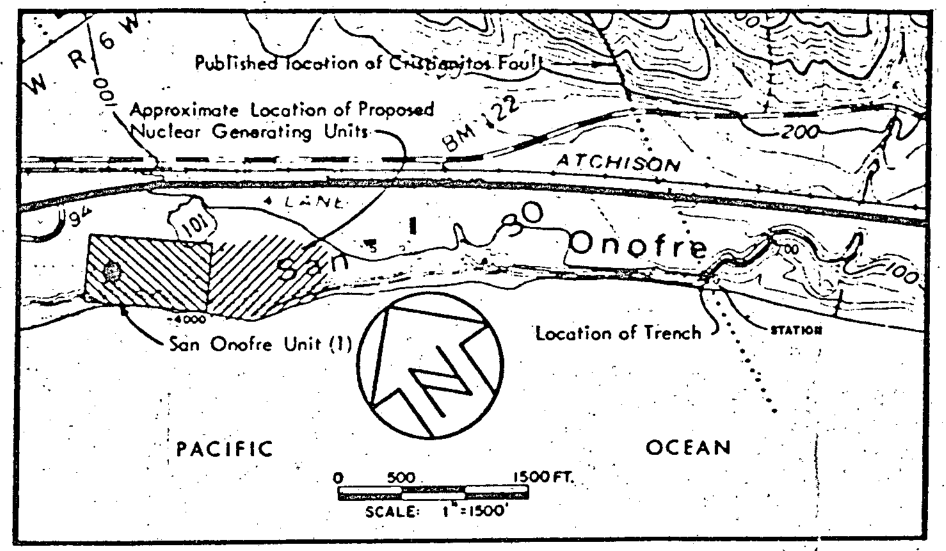
TRENCH LOG			
PREPARED BY: J.D.S. – G.D.T.	SAN ONOFRE BLUFF EXCAVATION for SOUTHERN CALIFORNIA EDISON COMPANY		DRAWING NO. 3
CHECKED BY: MDS			
APPROVED BY: [illegible]	DATE: APR. 13, 1970	SCALE: As Shown	PROJECT NO. 70-034-H
CONVERSE, DAVIS AND ASSOCIATES	PASADENA • SANTA ANA, CALIFORNIA		

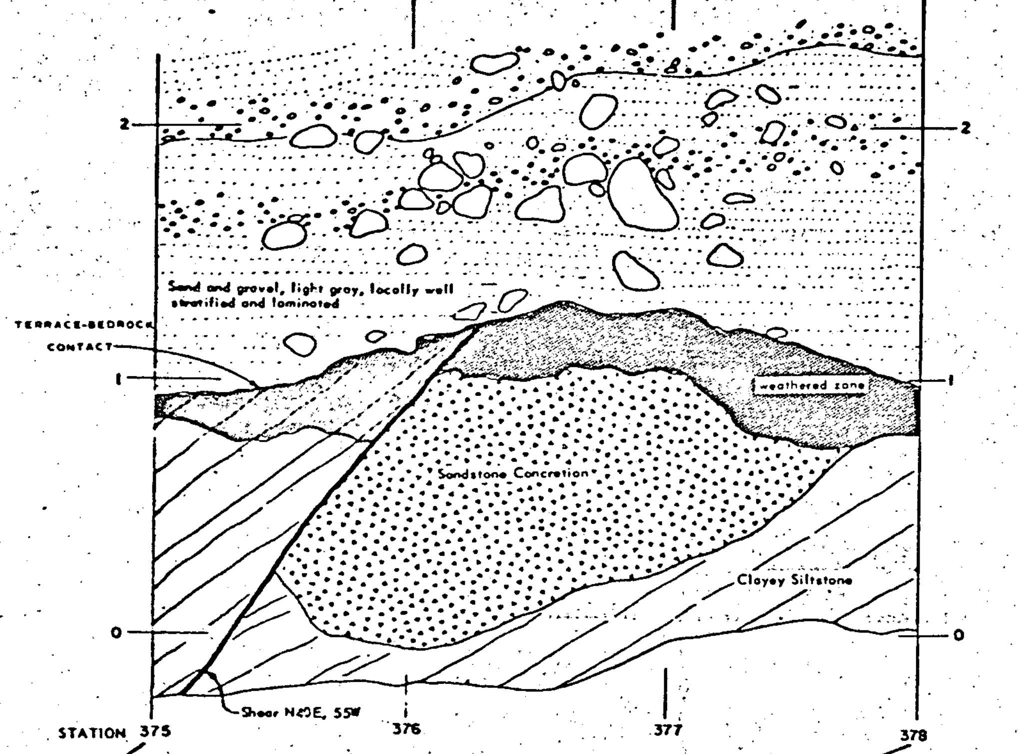
TRENCH LOG			
PREPARED BY: J.D.S-G.D.T.	SAN ONOFRE BLUFF EXCAVATION for SOUTHERN CALIFORNIA EDISON COMPANY		DRAWING NO. 4
CHECKED BY: DPS			
APPROVED BY: [illegible]	DATE: APR. 13, 1970	SCALE: As Shown	PROJECT NO. 70-034-H
CONVERSE, DAVIS AND ASSOCIATES	PASADENA • SANTA ANA, CALIFORNIA		



TRENCH PLAN
BRUNTON COMPASS SURVEY
SCALE: 1" = 75' Approx.

0 25 50 75 FT.
SCALE IN FEET





DETAIL LOG
SCALE: 1 Inch = 9 Inches Horizontal and Vertical

EXPLANATION

TERRACE

- Gravel and cobbles, gray to brown, in sand matrix, unstratified
- Sand and gravel, light gray, locally well stratified and laminated
- Sand, light gray to light brown, cross-bedded, thinly laminated with scattered lenses and stringers of gravel

BEDROCK

San Mateo Formation

- Sandstone, light brown to yellow brown

Capistrano Formation

- Clayey Siltstone, gray to dark gray, locally hackly with shiny parting surfaces; lines indicate apparent bedding orientations and emphasize displacements, weathered zone shown as dark stippling
- Clayey Siltstone, green, very contorted
- Silicified Sandstone or Siltstone concretion, brown to gray

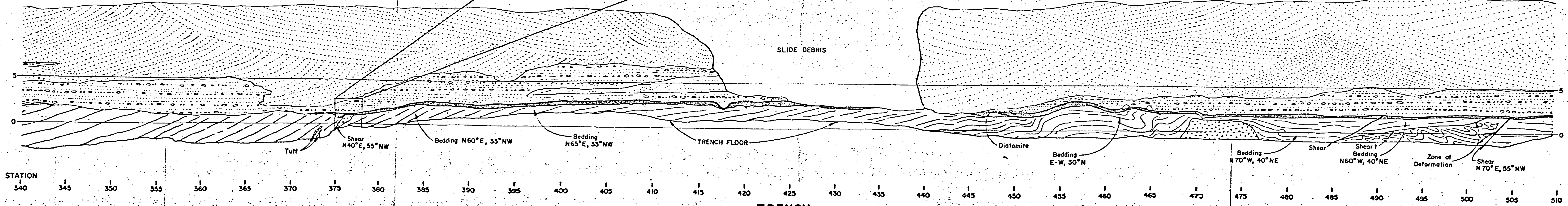
NOTE:
Minor lithologic variations described on log

SYMBOLS

- Geologic contact
- Strike and dip of bedding plane showing amount of dip in degrees
- Strike and dip of shear surface showing amount of dip in degrees
- Syncline, showing trend and plunge direction of axis
- Anticline, showing trend of axis

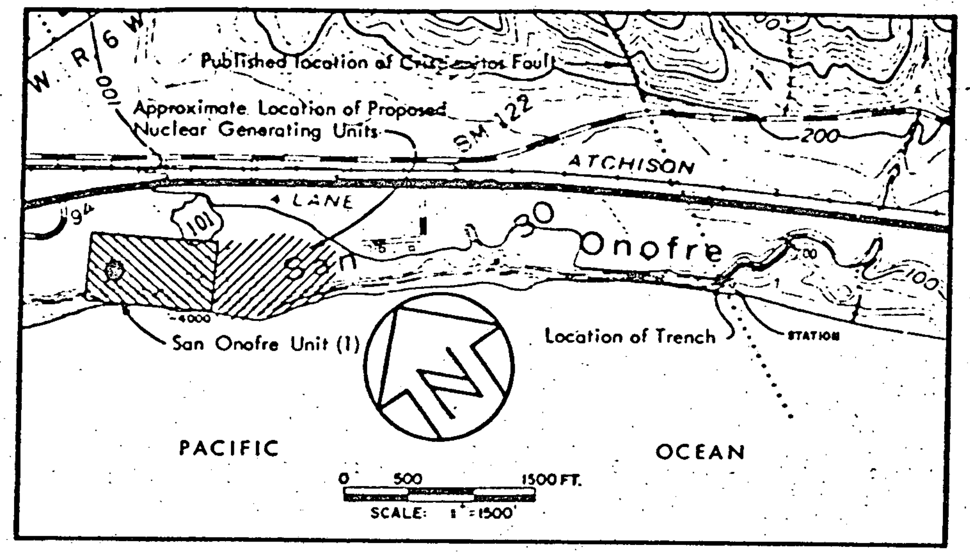
NOTE: Assumed elevation "0" corresponds to elevation 52.5', (top of seawall at elevation 28.0', Reference San Onofre Unit Nº 1).

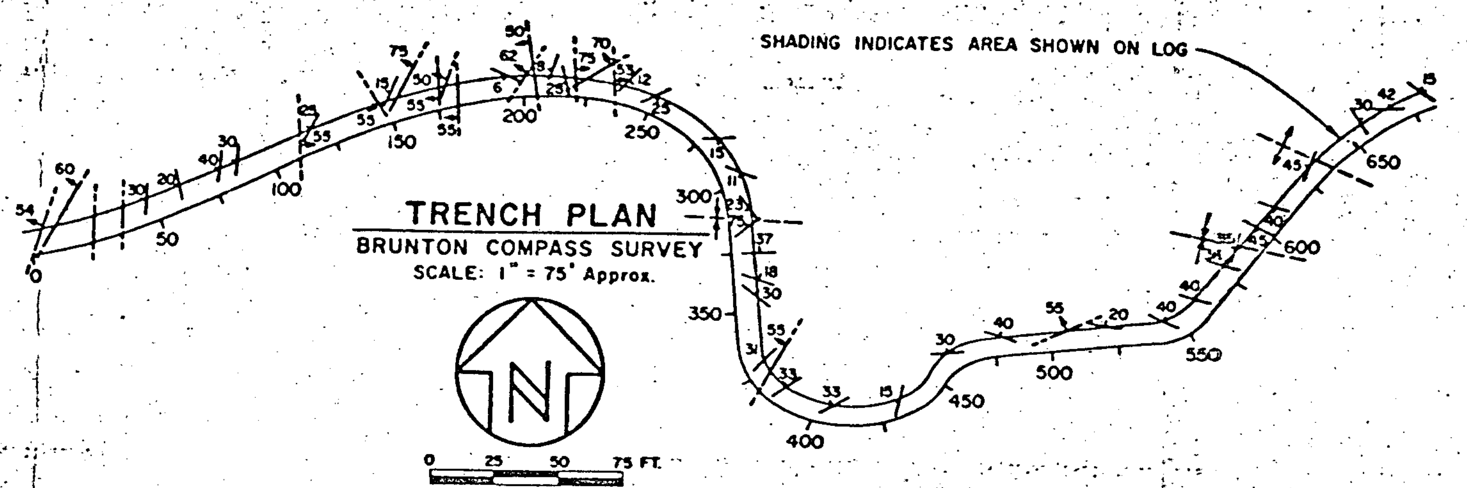
All elevations are assumed



TRENCH
LOOKING NORTH
SCALE: 1" = 7.5' Horizontal and Vertical
0 7.5 15 Feet

PREPARED BY: J.D.S. - G.D.T.	TRENCH LOG SAN ONOFRE BLUFF EXCAVATION for SOUTHERN CALIFORNIA EDISON COMPANY		DRAWING NO. 5
CHECKED BY: MDS			
APPROVED BY: KTD	DATE: APR. 13, 1970	SCALE: As Shown	PROJECT NO. 70-034-H
CONVERSE, DAVIS AND ASSOCIATES	PASADENA · SANTA ANA, CALIFORNIA		





EXPLANATION

TERRACE

- Gravel and cobbles, gray to brown, in sand matrix, unstratified
- Sand and gravel, light gray, locally well stratified and laminated
- Sand, light gray to light brown, cross-bedded, thinly laminated with scattered lenses and stringers of gravel

BEDROCK

San Mateo Formation

- Sandstone, light brown to yellow brown

Capistrano Formation

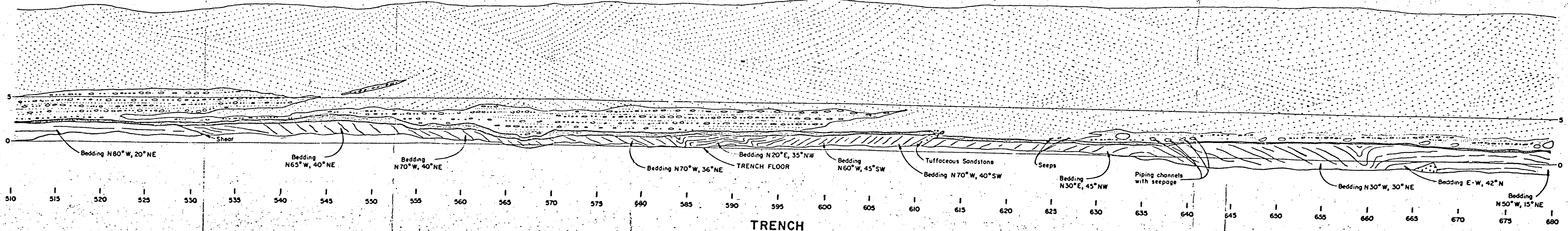
- Clayey Siltstone, gray to dark gray, locally hackly with shiny parting surfaces; lines indicate apparent bedding orientations and emphasize displacements, weathered zone shown as dark stipling
- Clayey Siltstone, green, very contorted
- Silicified Sandstone or Siltstone concretion, brown to gray

NOTE:
Minor lithologic variations described on log

SYMBOLS

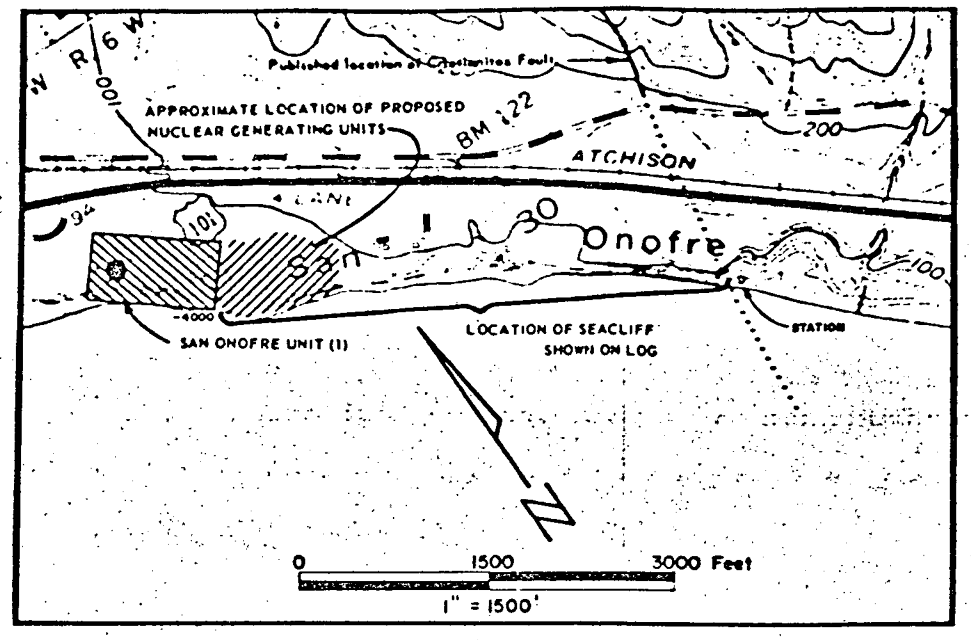
- Geologic contact
- Strike and dip of bedding plane showing amount of dip in degrees
- Strike and dip of shear surface showing amount of dip in degrees
- Syncline, showing trend and plunge direction of axis
- Anticline, showing trend of axis

NOTE: Assumed elevation "0" corresponds to elevation 52.5', (top of seawall at elevation 28.0', Reference San Onofre Unit № 1).
All elevation are assumed

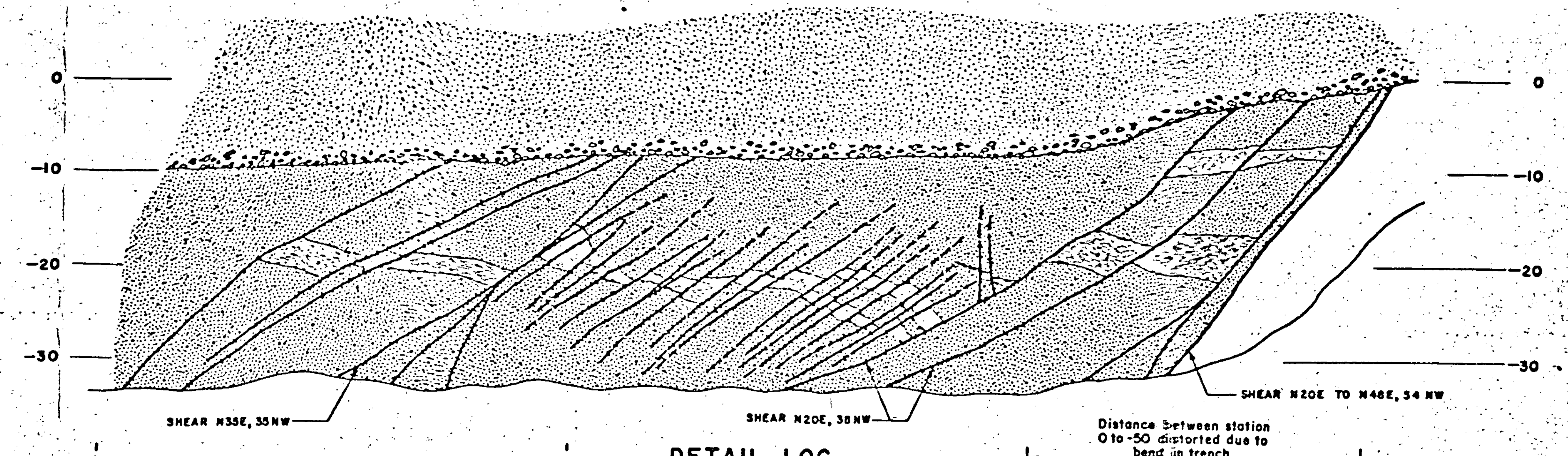


TRENCH
LOOKING NORTHWEST
SCALE: 1" = 7.5' Horizontal and Vertical
0 7.5 15 Feet

APPENDIX C



LOCATION MAP



DETAIL LOG

SCALE: 1" = 15' approximately
Horizontal and Vertical

EXPLANATION

TERRACE DEPOSITS; brown sand, silt and clay mixtures with gravel and cobble base, non-marine

SAN MATEO FORMATION; massive, cross-bedded, yellow-brown sandstone with scattered silty sandstone lenses and fragments (———)

CAPISTRANO FORMATION; gray to dark gray clayey siltstone

SEA CLIFF LOG		
PREPARED BY: J.D.S. - G.D.T.	SAN ONOFRE BLUFF EXPOSURE for SOUTHERN CALIFORNIA EDISON COMPANY	DRAWING NO. 6
CHECKED BY: JDS		
APPROVED BY: [signature]	DATE: APR. 13, 1970 · SCALE: As Shown · PROJECT NO. 70-034-H	
CONVERSE, DAVIS AND ASSOCIATES	PASADENA · SANTA ANA, CALIFORNIA	

NOTES:

All elevations shown on log are assumed

Assumed elevation "0" corresponds to elevation 52.5', (top of seawall elevation 28.0', Reference: San Onofre Unit 1)

Logs drawn from photographs, therefore, scale is somewhat distorted

SEA CLIFF

LOOKING NORTHEAST

SCALE: 1" = 75' Horizontal and Vertical

0 75 150 225 Feet

SCALE IN FEET

APPENDIX D

DESCRIPTION AND LOG OF EXPLORATORY EXCAVATION

IN TRABUCO CANYON

APPENDIX D

DESCRIPTION AND LOG OF EXPLORATORY EXCAVATION IN TRABUCO CANYON

1. EXCAVATION METHODS

The Plano Trabuco excavation, shown in Drawing No. 6, is on the north side of Tijeras Creek about 6000 feet northeast of the intersection with Arroyo Trabuco. The purpose of the trench was to obtain age and displacement data on the Cristianitos fault near its northern end.

The excavation is a steep cut about 35 to 45 feet high and about 140 feet long. A broad horizontal bench was excavated about mid height across the slope and a vertical cut about ten feet high was graded along the toe. This vertical wall was carefully scraped and cleaned to expose the bedrock and overlying non-marine terrace deposits. A grid was constructed and the contacts were logged at scales of five feet and two feet to the inch.

2. LITHOLOGY

2.1 Bedrock

The southern portion of the excavation (approximately between Stations 0 and 52) consists of a massive, light gray and light brown sandstone tentatively assigned to the Topanga Formation. The sandstone varies from fine to coarse grain and contains some scattered rounded gravel. Between Stations 0 and 27 an irregular, gray-brown layer of clay about one foot thick overlies and is incorporated into the sandstone. This clay has a bentonitic appearance and forms elongate pods and lumps which are sometimes interconnected by thin dike-like necks.

The northern end of the trench between Stations 97 and 140 exposes a gray-green siltstone thought to belong to the Vaqueros Formation. The siltstone is moderately hard, indistinctly bedded, and has vary hackly fracture. A layer of white tuff about one to three feet thick overlies the siltstone and has been eroded locally by stream cutting prior to terrace deposition.

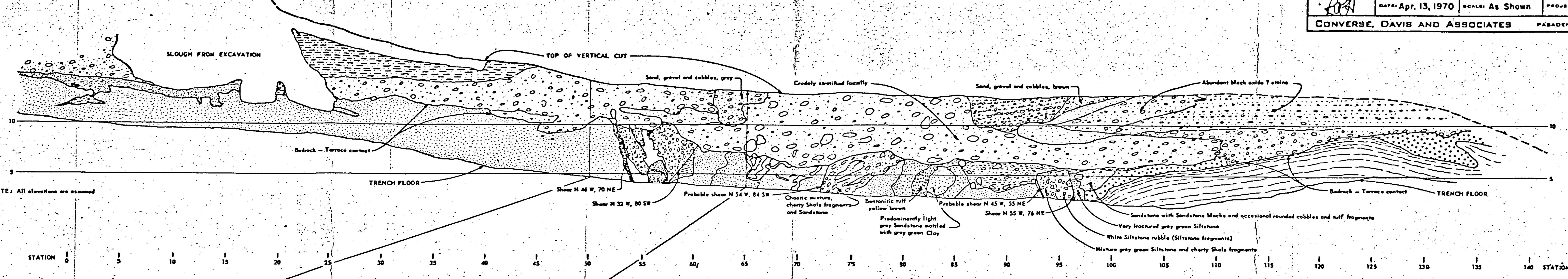
Between Stations 52 and 97, a sheared and contorted zone separates the sandstone and siltstone. The rocks within the zone consist of combinations of sandstone, siltstone, clay, gravelly rubble, and lesser amounts of bentonitic tuff and fragments of cherty shale. The sandstone is light gray, fine to medium grained, and soft. The siltstone is gray-green and usually mixed with the sandstone. The rubble is a random mixture of red-brown gravel and cobbles in a silty sand matrix. The clasts are subangular and derived mainly from metamorphic and igneous rocks. Interspersed through the rubble and various other rocks in the disturbed zone is a gray-green clay with numerous shiny parting surfaces and scattered sand and gravel. Scattered small fragments of gray-green siltstone were also observed. The irregular configuration of the clay contact, the incorporation of surrounding materials into the clay, and the presence of shiny parting surfaces indicate the clay has undergone great strain which has caused the material to perform plastically.

Three distinct shear surfaces were observed and measured in the bedrock at Stations 52, 57 and 97. In order to insure that the shears were reasonably continuous, the surfaces were exposed along the trench floor as well as on the wall. The trends of these shears varied from north 32 to 55 degrees west and the dips varied from 80 degrees southwest to 76 degrees northeast. The surfaces were generally not well exposed and no definite slickensides were observed. Thickness of gouge along the shears was less than six inches and generally only several inches. The apparent thickness of the contorted zone measured along the trench is about 45 feet, but the actual width of the zone is only 25 feet measured normal to the trend of the shears.

2.2 Terrace Deposits

The non-marine terrace deposits consist of various combinations of silt, sand, gravel and cobbles. The cut exposed between 30 and 40 feet of these stream deposited sediments unconformably overlying the bedrock. The terrace materials tended to be coarser and more clearly stratified near the terrace-bedrock contact. Toward the top of the cut the materials graded to a nearly massive light brown silty sand with streaks of coarse sand, with scattered layers of gravel and sparse organic debris. The terrace deposits logged above the bedrock consisted of well-stratified and randomly mixed combinations of silt, sand, gravel, cobbles and scattered boulders. Despite the fact that the terrace units logged are irregular and unconformable, many were well-stratified and provided lines of reference demonstrating that displacements in the bedrock did not extend into the terrace materials.

Careful inspection and logging of the bedrock, terrace deposits and the contact between the two indicate that the shearing in the bedrock does not displace the non-marine terrace deposits.

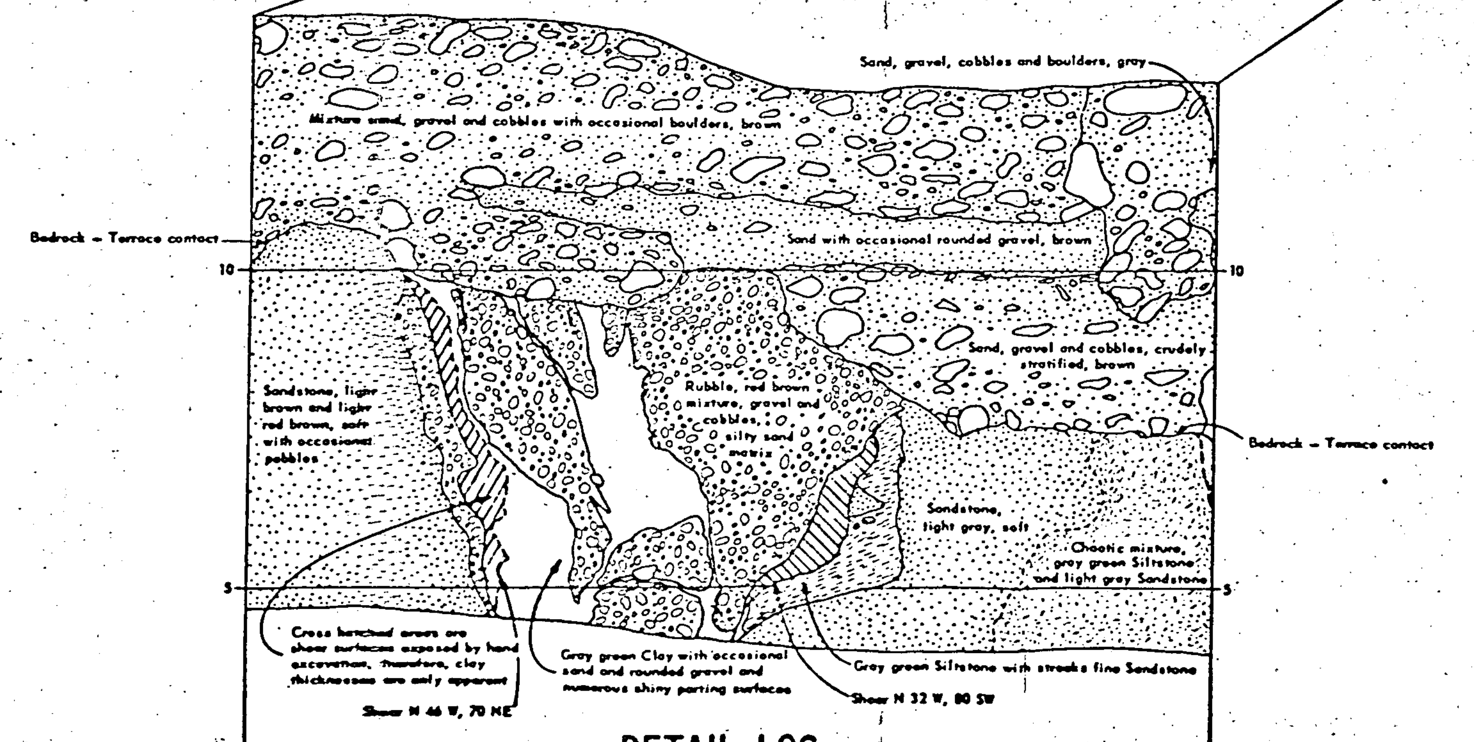


TRENCH

Looking West

SCALE 1" = 7.5'

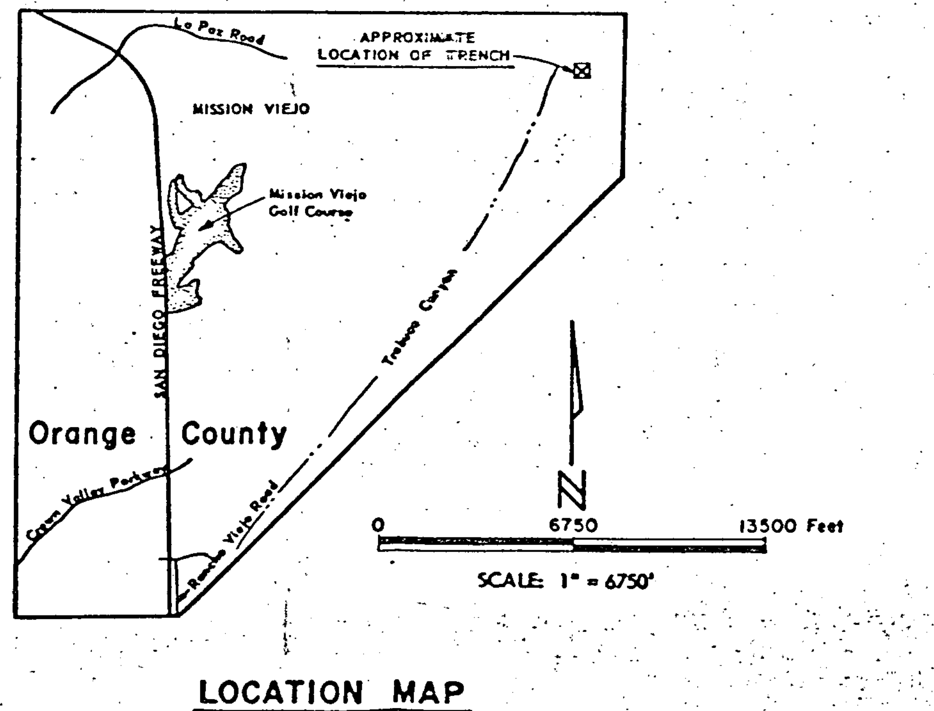
HORIZONTAL AND VERTICAL



DETAIL LOG

SCALE: 1" = 3'

HORIZONTAL AND VERTICAL



LOCATION MAP

EXPLANATION

TERRACE	BEDROCK
Sandy Silt, brown with occasional gravel	Sandstone, light gray and light brown, fine to coarse grain with occasional cobbles, massive
Sandy Clay, brown with rounded cobbles	Siltstone, gray green moderately hard, hackly fracture, indistinct bedding
Sand, brown, fine grain	Rubble, red brown chaotic mixture, gravel and cobbles size clasts (subrounded) in silty sand matrix
Sand with occasional cobbles and gravel, brown and light brown	Clay, gray green with occasional fragments of gray green Siltstone and small amounts of sand
Sand, gravel, cobbles and occasional boulders, random mixture	Tuff, white, concoidal fracture, moderately hard
Sand, gravel and cobbles, crudely stratified, with black oxide ? stains	Chaotic mixture, gray green clay and gray Sandstone, fine
Sand and gravel, well stratified	Clay, brown gray, weathered, appears like bentonite (altered tuff)
Gravel and cobbles, well stratified	

TRENCH LOG			
PREPARED BY: J.D.S.-G.D.T.	PLANO TRABUCO EXCAVATION MISSION VIEJO RANCH for SOUTHERN CALIFORNIA EDISON COMPANY		DRAWING NO. 7
CHECKED BY: JDS			
APPROVED BY:	DATE: Apr. 13, 1970	SCALE: As Shown	PROJECT NO. 70-034-H
CONVERSE, DAVIS AND ASSOCIATES	PASADENA - SANTA ANA, CALIFORNIA		