Central Files

SAFETY EVALUATION

OF THE GEOLOGIC FEATURES

AT THE SITE OF THE SAN ONOFRE NUCLEAR

GENERATING STATION

Docket Nos. 50-206
50-361
50-362

U. S. NUCLEAR REGULATORY COMMISSION

Office of Nuclear Reactor Regulation

July 8, 1975

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX

1. INTRODUCTION

This report presents our evaluation of the investigation of several geologic discontinuities revealed in the excavations for the San Onofre Nuclear Generating Station (SONGS) Units 2 and 3. These discontinuities, hereafter referred to as features A, B, C, and D, are minor shear zones or minor faults. This evaluation incorporates the findings of three site visits by the Nuclear Regulatory Commission (NRC) staff and the review of two reports of investigations conducted for the applicant by Fugro, Inc.

The objective of this report is to present our review and conclusions about the safety implications of the geologic discontinuities. We have analyzed the characteristics of the A, B, C, and D features, and determined their relative ages, origin, and relationships to each other. We have also considered their safety significance to the San Onofre site in view of the plant seismic design.

On June 5, 1974, the Southern California Edison Company, on behalf of itself and the San Diego Gas & Electric Company, (hereafter referred to as the applicant), orally advised us that anomalous geologic features had been discovered during the excavation for Units 2 and 3 at the San Onofre site. That communication was followed by a letter from the applicant to the Director of Licensing, dated June 7, 1974.

In his response of June 10, 1974, the Director of Licensing directed the applicant to:

(1) Investigate the significance of the exposed geologic features and their effect on the continued adequacy of the seismic design of Units 1, 2, and 3.

(2) Submit within thirty days written statements under oath or affirmation analyzing the effect of the geologic features on the adequacy of the seismic design for Units 1, 2, and 3.

(3) Investigate and report any additional geologic features that might be discovered through the completion of excavation at the San Onofre site.

Between June 8-11, 1974, members of the staff, accompanied by U. S. Geological Survey (USGS) geologists, examined foundation exposures at the site of SONGS 2 & 3. Two items of geologic significance were noted:

(1) A conjugate set of linear shear zones or faults (designated A and B type features by the applicant) within the San Mateo Formation. These shears exhibit minor mutual displacement of not more than 4 inches at their intersection.

(2) An apparent vertical offset of the San Mateo Formation which was later determined to be an erosional contact.

The applicant subsequently analyzed these features and on July 12, 1974, reported its findings and conclusions in a document titled "Analysis of Geologic Features at the San Onofre Nuclear Generating Station".

The USGS geologic advisor to the staff investigated these features at the site and also reviewed the applicant's report. A draft report of the USGS review, transmitted to the staff on August 1, 1974, is appended to this report.

On September 11, 1974, the applicant informed us of the discovery of two additional geologic features in the San Mateo Formation (in addition to the A and B features). These were uncovered in the course of deepening the excavation for Unit 2. The applicant designated these the C and D features. On October 3, 1974, staff geologists visited the site to examine exposures of the C and D features in the site excavation and to discuss the applicant's on going investigation. Subsequently, on November 1, 1974, the applicant submitted a report prepared by Fugro, Inc. entitled, "Analysis of C and D Type Features at the San Onofre Nuclear Generating Station." A final, comprehensive report of investigations of all geologic features observed during excavation will be submitted to the NRC following completion of all site excavations.

2.0 EVALUATION

2.1 Synopsis of Site Geology

The San Onofre site is in the Peninsular Range Physiographic Province of California. The province is characterized by northwest trending faults and physiographic features that extend from the Transverse Ranges southward into Mexico. The site is on the narrow, gently sloping coastal plain which extends seaward from the Peninsular Range uplands. The plain is terminated at the sea shore where it forms a relatively straight seacliff rising 60 to 80 feet above sea level. Erosion has resulted in deeply incised barrancas being cut into the coastal plain terrace in the plant site area.

In the site area a Pleistocene terrace deposit of non-marine and marine origin is exposed in the seacliff where it overlays the San Mateo Formation of Pliocene age. During the Pleistocene, action eroded a gently seaward sloping bench in the San Mateo Formation which was later covered by poorly stratified terrace deposits. These deposits are now between 30 and 50 feet in thickness. Potassium-argon dating shows the terrace to be approximately 100,000 years old.

2.2 Lithology

2.2.1 San Mateo Formation: The San Mateo Formation of Pliocene or Mio-Pliocene age is widely distributed west of the Cristianitos Fault. It is well exposed along the sea coast, and underlies the SONGS site. The formation consists predominantly of massive, light-brown to light-gray, arkosic sandstone with scattered interbeds of gravel consisting of rounded pebbles, and layers of fine grained silty sandstone and siltstone. The sandstone is slightly cemented and forms steep canyon walls and nearly vertical cliffs along the sea coast. Locally, large fragments of siltstone and claystone, up to 10 feet in diameter, have been found in the San Mateo sandstone. These are believed to have been deposited by turbidity currents or submarine slumping during deposition.

2.2.2 Terrace Deposits

Pleistocene marine and non-marine deposits have been recognized in the site vicinity. The primary Pleistocene terrace deposit in the site area is described as follows: Unit Qt_1 is a series of crudely stratified mixtures of brown to gray brown sand, silt, and clay with scattered lenses and layers of gravel, cobbles and boulders. This unit represents both marine (Qm) and non-marine terrace materials deposited over wave cut benches and along the low flank or flood plains of San Mateo and San Onofre Creeks. Source material for the terrace deposits was detrital debris from the foothills. At the site, marine terrace deposits (Qm), a subdivision of Qt_1, occur as small, localized pockets within erosional irregularities in the San Mateo Formation. At the SONGS site, the terrace materials (Qt_1) have been deposited on a broad, gently sloping coastal plain that is extensively developed along the San Onofre coast. The thickness of Qt_1 (including Qm) ranges from 30 to 50 feet with Qm being the lower 5 feet in localized areas.

Age dating of California coastal terraces has been accomplished by three different approaches: (1) minimum dating by use of Carbon-14; (2) dating shell materials by the use of Thorium-protactinium disequilibrium determinations; and (3) inferences based on regional terrace elevations. Although no fossils were found locally in the Qt_1 unit, mollusks have been recovered from marine terrace deposits about 4.5 miles south of the site and were dated by the Potassium-argon method at 160,000 years (minimum age) (PSAR, Section 2.9.4). Thorium-protactinium age dating of shell materials collected from two localities in a correlative terrace, at distances of 10 and 18-1/2 miles northwest of the SONGS site, gave ages of 120,000 and 70,000 years, respectively. This indicates that the Qt_1 terrace has a minimum age of 70,000 years. Ku and Kern (1974)* state, however, that in the dating of mollusks from the Nestor terrace and a topographically lower terrace near San Diego, they apparently obtained unreliable results because mollusk shells often act as "open systems" which allow post-depositional migration of uranium and thorium isotopes. These authors alternatively present data on the dating of corals (which are contended to act as a closed system) from the Nestor terrace which indicate that the Nestor terrace has a minimum age of 120,000 years. This age, plus ages spanning the interval between 68,000 and 124,000 years for terraces elsewhere along the California coast (Ku and Kern, 1974)*, suggest that widespread terrace cutting occurred along

---

*Ku, T. L. and Kern, J. P., Uranium-Series Age of Upper Pleistocene Nestor Terrace, San Diego, California, Bull. Geol. Soc. America, Vol. 85, p. 1713-1716, Nov. 1974 this coast during a stillstand of the sea approximately 120,000 years ago. Other high sea stands were also believed to have occurred at about 105,000 and 80,000 years ago. It can be concluded with some confidence, therefore, that the Qt_1 terrace in the vicinity of the SONGS site was developed about 100,000 years before the present (Y.B.P.).

2.3 Discontinuities

Four types of geologic discontinuities were observed in the San Mateo Formation in the excavations for SONGS 2 and 3:

(1) Shear zones demonstrating up to 4 inches of strike-slip movement; Type A shears trend north and north-northeast, Type B shears trend about N 50°W; these appear to be a conjugate set of shears.

(2) A minor shear zone feature, 60 feet in lateral extent which exhibited no obvious evidence of displacement; this Type C feature strikes N 50°W to N 60°W and dips between 5° and 19°NE.

(3) A minor thrust fault consisting of a series of individual hairline fractures containing no crushed material. This Type D feature exhibits a maximum observed reverse movement of 2-3/4 inches, strikes approximately N 70°W and dips between 15° and 20°NE.

(4) Color banding due to ground water interaction with the rock.

Minimum ages of the A, B, and D features were established by the overlying terrace deposits described above. The Type C feature is minor and is believed to be contiguous with the Type D feature. None of these features displace the terrace deposit San Mateo contact and, as a result, all are considered older than the terrace deposit (70,000 Y.B.P.). Detailed discussions of these features and their relationship to the site follow.

2.4 Origin and Age of Formation of Discontinuities

2.4.1 Features A and B

The first two sets of shear zones originally discovered in the site area were identified in the applicant's July 12, 1974 report as Type A shears which strike between north and N 10°E, and Type B shears, which strike approximately N 50°W. The two sets of shears have a similar appearance caused by crushing of sand grains along the shear planes. They are as much as 10 inches wide, are essentially linear, and dip nearly vertical. A typical shear zone is shown in Photo No. 1, where its linearity is apparent. The Type A shear zones, which occur in four principal strands, converge northerly in the site area and completely traverse the site. Their northerly and southerly extent has not been determined. Six strands of the Type B shears are exposed in the site. These continue beyond the site to the northwest, but all visible strands of this set terminate in the southeasterly direction within the site excavation.

Where the two sets of shear zones intersect, each offsets the other. The maximum total displacement at their intersections and across clay inclusions has been observed not to exceed 4 inches (See Photos 2, 3, and 4). The sense of displacement is consistently left lateral for the Type A shears and right lateral for the Type B shears, indicating the development of a conjugate set of fractures.

Shear zones similar to those at the site are reported in the applicant's investigation as occurring in an abandoned quarry 1.7 miles northwest of the site and along the sea cliff approximately the same distance northwest of the site. Wherever the shear zones are observed in an exposure with overlying terrace deposits, they are truncated by the terrace deposits, as illustrated in Photo 5. This relationship indicates that the shear zones were formed within the San Mateo Formation prior to the deposition of the overlying terrace deposits. Thus they can be assigned a minimum age of 70,000 to 120,000 years based on the age of terrace deposits which overlie the eroded surface of the San Mateo Formation.

Three possible origins for the Type A and Type B shear zones were suggested by the applicant: (1) stress release caused by removal of lateral support by erosion along the seacliff, (2) fractures caused by movement on the Cristianitos Fault (which strikes N-S about 3,000 feet inland of the site), and (3) minor regional shearing resulting from northwest-southeast compressional stresses. We consider the first of these postulated origins to be highly unlikely. The orientation of the fractures and their mutually offsetting relationship are inconsistent with a stress release mechanism caused by seacliff erosion. While the second postulated cause is possible, we consider it unlikely also because the shears are widely distributed and show no increase in frequency toward the Cristianitos Fault. We and our consultant, the USGS agree, however, that the third of the mechanisms postulated by the applicant does offer an acceptable interpretation of the observed shear zones. The shear zones form a conjugate set consistent with the application of regional compressive forces in a northwest-southeast direction.

We further concur with the applicant's statement on page B-2 of the July 12, 1974 report, "The appearance of the shear features warrants the tentative conclusion that the height of the overlying material at the time of shearing was greater than prior to removal of about 70 feet of overburden for

Units 2 and 3. Crushing of grains along the shear planes would not be likely if only tens of feet of material overlay the San Mateo Formation. This suggests shearing occurred prior to the development of the marine terrace platform." This observation is based on the applicant's evaluation of data relating the degree of grain crushing which occurs in the shear zones (Vesic and Clough, 1968)*. Evaluation of the mechanics of shear fracture indicates that shears of Types A and B could have developed at a mean lithostatic stress about 20 to 30 grams per square centimeter or greater. This would indicate a possible overburden height above the shear features of about 300 feet at the time of their formation. Ku and Kern (1974) estimate an average uplift of the San Diego coastal area of 11 to 14 centimeters per 1000 years. This rate of uplift suggests an age of formation of the Types A and B shear zones of as much as 830,000 Y.B.P.

The data used by the applicant assume a dry rock condition. The existence of pore pressures (i.e., water pressure developed in a porous and permeable rock) could complicate this analysis. The presence of a high pore water pressure could allow the same fractures and gouge development to occur as indicated above at even greater depths of burial. Thus an even greater expanse of time may have elapsed since these features were formed.

---

*Vesic, A. S., and Clough, G. W., Behavior of Granular Materials Under High Stresses, Proc. ASCE, V. 94, Jour. Soil Mech. and Found. Div., SM3, P. 661-688, May 1968

2.4.2 Apparent Fault

An apparent offset in the marine terrace deposits was discovered in the south wall of a barranca just east of the Unit 2 during excavation. The exposure appeared at first to be a fault with vertical offset of approximately 11 feet juxtaposing the marine terrace deposits (Qm) and the San Mateo Formation. The plane of apparent offset approximately coincides with and is aligned with one of the Type A linear shear zones in the San Mateo Formation.

The alignment of the contact between Qm on the San Mateo Formation conveys the initial impression that the terrace deposit (Qt_1) to the right of the shear alignment, (see upper right of Photo 6), is displaced downward. Photos 7 and 8 are closeup views of the shear zone-terrace contact from the landward and seaward sides, respectively. The photos show the shear zone to be clearly truncated by the marine terrace deposit (Qm). Wherever the shear zones are observed to intersect the terrace deposits - San Mateo Formation contact, no offset of the contact is visible.

Within the site excavation, the Type A shear zones intersect three of the clayey silt boulders found within the San Mateo Formation. Offsets through these boulders demonstrate that movement along the shear zones has not exceeded a few inches, is left lateral, and has no apparent vertical component. These properties of the shear zones are clearly illustrated in Photos 9 and 10. In these photos, a clay boulder in the seacliff below the apparent offset terrace is seen to be intersected by the Type A shear. The plane of the shear is marked by the two nails at the top and bottom of the boulder. The 10 foot apparent vertical displacement seen in the terrace deposit is incompatible with the little or no vertical offset in the boulder.

Detailed geologic mapping of the seacliff, where the apparent terrace offset was found, showed that the shear zone was capped by the marine terrace deposit (Qm) (Photos 7 and 8) which is locally present in this area.

Upon careful removal of the marine terrace deposit, it was found that the plane of contact between the marine terrace deposit and the San Mateo Formation was irregular, as shown in Photos 11 and 12. This confirms that the plane of contact which initially appeared to be a fault plane is an erosional surface (Photo 12). Representatives from the staff and the USGS were present when the marine terrace contact was exposed by excavation and concur with the applicant's interpretation that the contact is of erosional origin. We conclude that the marine terrace deposit (Qm) materials were deposited in an erosional channel developed within the San Mateo Formation.

2.4.3 Feature C

Feature C consists of a sinuous zone of thin (1/8 to 1/4 inch), white, resistant ribs similar to the Type A and Type B features. The average strike of this zone is N 50°W to N 60°W and it dips between 5° and 19°NE. The zone extends approximately 60 feet through an excavation cut-slope northeast of Unit 3. Displacements on the zone have not been clearly recognized, with the exception of a questionable 2-1/2 inch right lateral offset of a thin clay seam. It has the crushing and gouge characteristics of the Type A and Type B shear zones and probably is contemporaneous with them in origin. This fracture has not been observed to intersect either the Type A or B features or the terrace deposits. Its similar properties to the Type A and B features indicate, however, that the features had a contemporaneous development.

2.4.4 Feature D

The Type D feature consists of individual hairline fractures which continue across the excavations for Units 2 and 3, but terminate in the north and west cut-slopes of the Unit 2 excavation. This feature has a distinctly planar surface and contains no gouge, cementation, or crushed material. It is, thus, dissimilar to the Type A, B, and C features. The sense of movement on the Type D feature indicates that it is a minor thrust fault with maximum observed reverse movement of 2-3/4 inches. It strikes approximately N 70°W and dips between 15° and 20°NE. The attitude of the fault correlates closely with interbedding or grading in the San Mateo sandstone.

The age of fault D can be determined by its relationship to the Type A and Type B shear zones (it does not intersect the Type C feature), the color banding (a remnant of ground water action), clay inclusions, and the overlying terrace deposits. Where fault D intersects the above features, they are offset in a reverse direction with the notable exception of the terrace deposit. During our October 3, 1974 site visit, we followed fault D easterly from the Unit 3 excavation to the location where it intersects the terrace deposits. The applicant had exposed the fault-terrace contact by trenching at that point. We closely examined and photographed the contact and we conclude that the fault is truncated by the terrace deposit and therefore, predates it. We, therefore, conclude that fault D is younger than the Type A and Type B shear zones but older than the terrace deposits.

An evaluation of the mechanics of fracture by the applicant led to the conclusion that fault D, with its absence of a crushed zone and gouge material, was formed at mean lithostatic stresses below about 10 kilograms per square centimeter.

This would indicate that overburden thickness was about 60 feet at the time of its formation. Fault D was, therefore, formed when the upper level of the San Mateo Formation was not much different than its present elevation, but before the deposition of the overlying terrace deposits.

Again the applicant's evaluation of the mechanics of fracture assumed dry rock conditions and does not take account of variations in pore pressure. High pore pressure at the time fault D was formed could account for the development of fracture and displacement without extensive crushing or gouge development. The possibility thus exists that fault D could have developed at a considerably greater depth of burial. It, therefore, appears that the applicant has taken a conservative position with regard to the development and age of fault D.

2.5 Regional Stress Conditions

The applicant has developed a concise and acceptable history for the evolution of the Type A, B, and D features and the Type C feature can be related to these. The applicant's history follows:

"Therefore, the sequence of events is that during some stage after the formation and probably at least partial consolidation of the San Mateo material, a north-south component of horizontal stress began to increase. At the same time, an east-west component decreased. These stress changes eventually resulted in the generation of the nearly vertical conjugate set of A and B features in the formation at a depth of at least 300 feet below the upper surface existing at that time (Drawing 20A). The lateral extension permitting the reduction in the east-west component eventually stopped when the shearing displacement reached the level currently observed. Erosion of the upper surface proceeded, lowering the surface by about 200 feet, when the generally north-south compression continued, or was reactivated with some rotation towards a more northerly direction. The consequence at this time was the development of the D shear feature (Drawing 20B). It is concluded that this shear was generated when the upper level of the San Mateo was not much different from its present elevation but before deposition of the overlying terrace gravels."

3.0 CONCLUSIONS

We and our geologic consultant, the USGS, have reviewed the applicant's report, "Analysis of Geologic Features at the San Onofre Nuclear Generating Station." We have also visited the site with the USGS to examine the apparent vertical offset in the marine terrace deposits exposed in the seacliff. We have examined the Type A and Type B features exposed at the San Onofre site. Based on our review and evaluation, we conclude that these geologic features are not capable faults as defined in Appendix A to 10 CFR Part 100.

In addition, the staff has reviewed the applicant's report, "Analysis of C and D Type Features at the San Onofre Nuclear Generating Station." We believe that this report satisfactorily explains and dates the occurrence of the C and D features. The conclusions reached by the applicant appear to be valid and well documented. We have also visited the site and examined the Type C and Type D features. Based on our review and evaluation, we conclude that the Type C and Type D features are not capable faults as defined in 10 CFR Part 100, Appendix A.

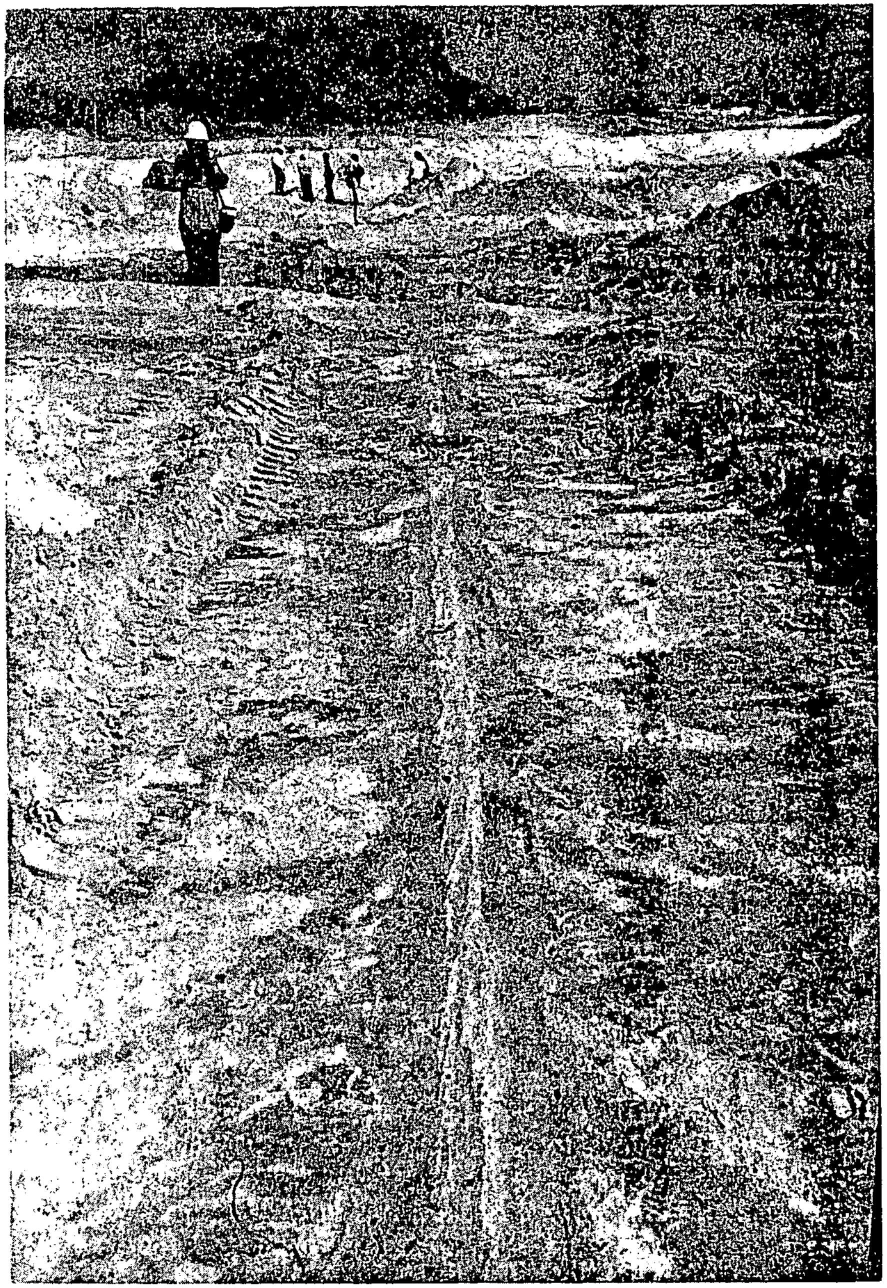

Figure 1

View of one of the Type B shear zones facing southeasterly.

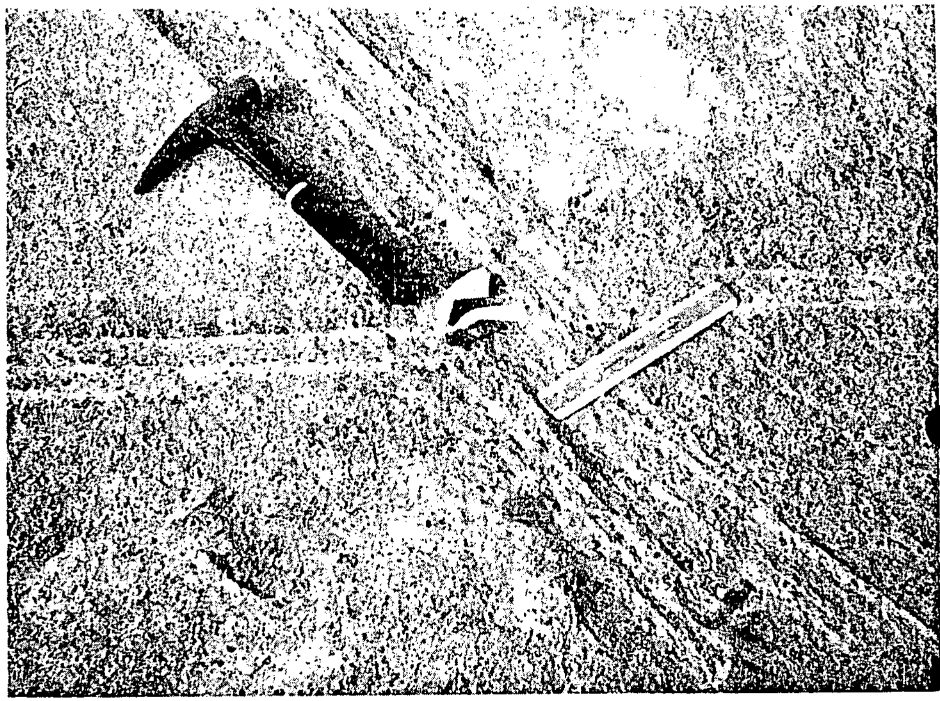

Figure 2

Intersection of a Type A and Type B shear zone showing the mutual offset relationship.

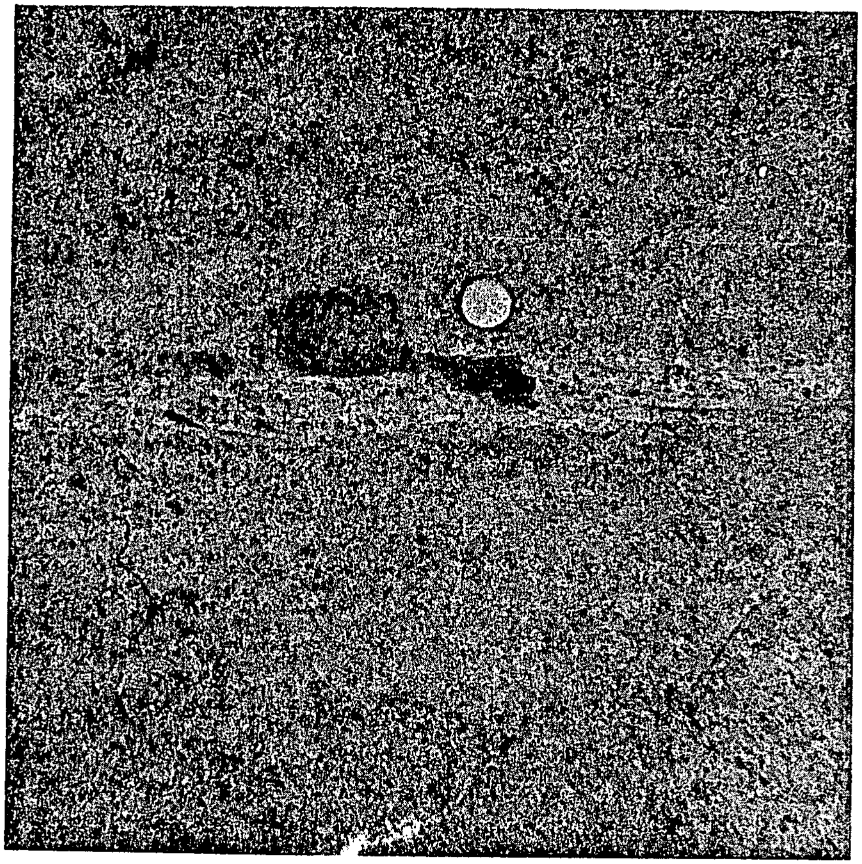

Figure 3
Clay silt inclusion offset by Type A shear zone. Coin is a quarter.

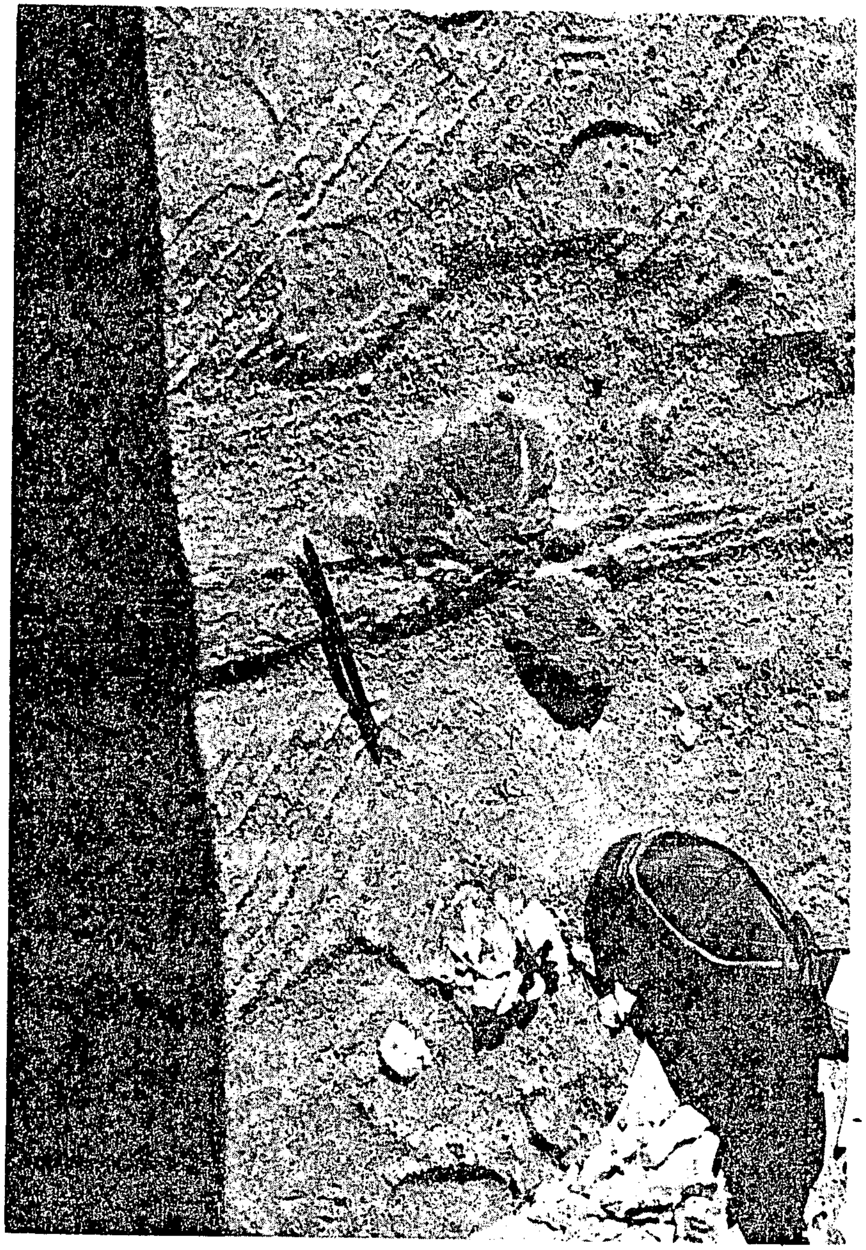

Figure 4
Clay silt inclusion intersected by Type A shear zone.

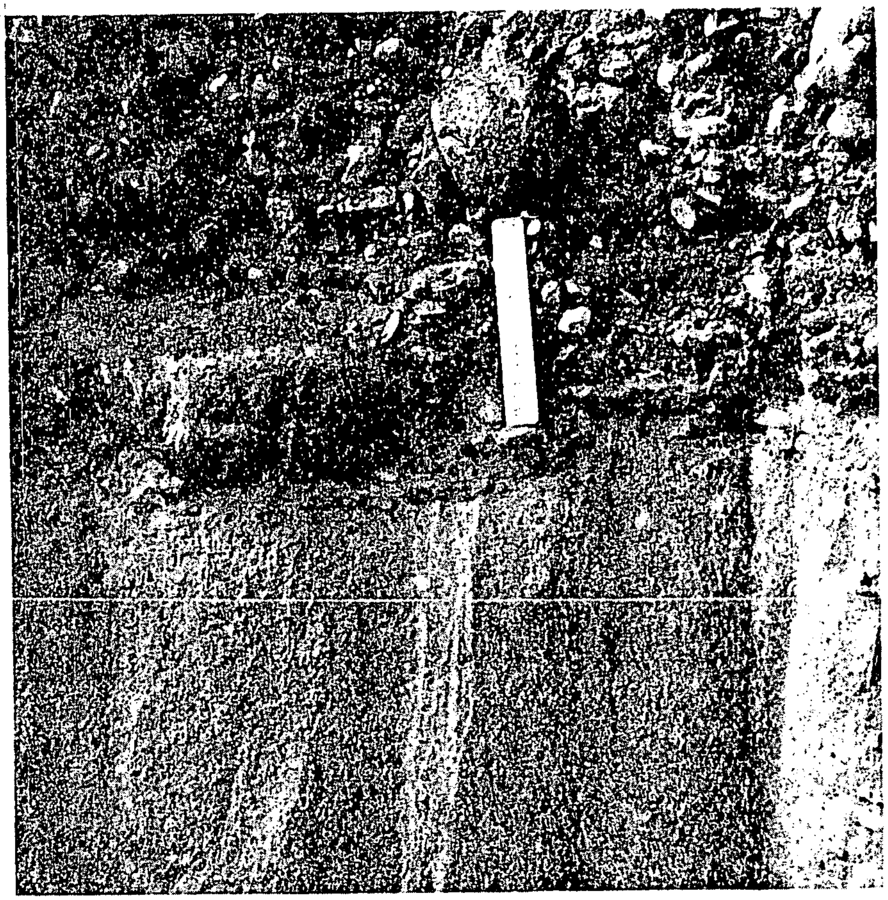

Figure 5
Type A shear zone in San Mateo Formation truncated by terrace deposit. Cast of Unit 2 excavation.

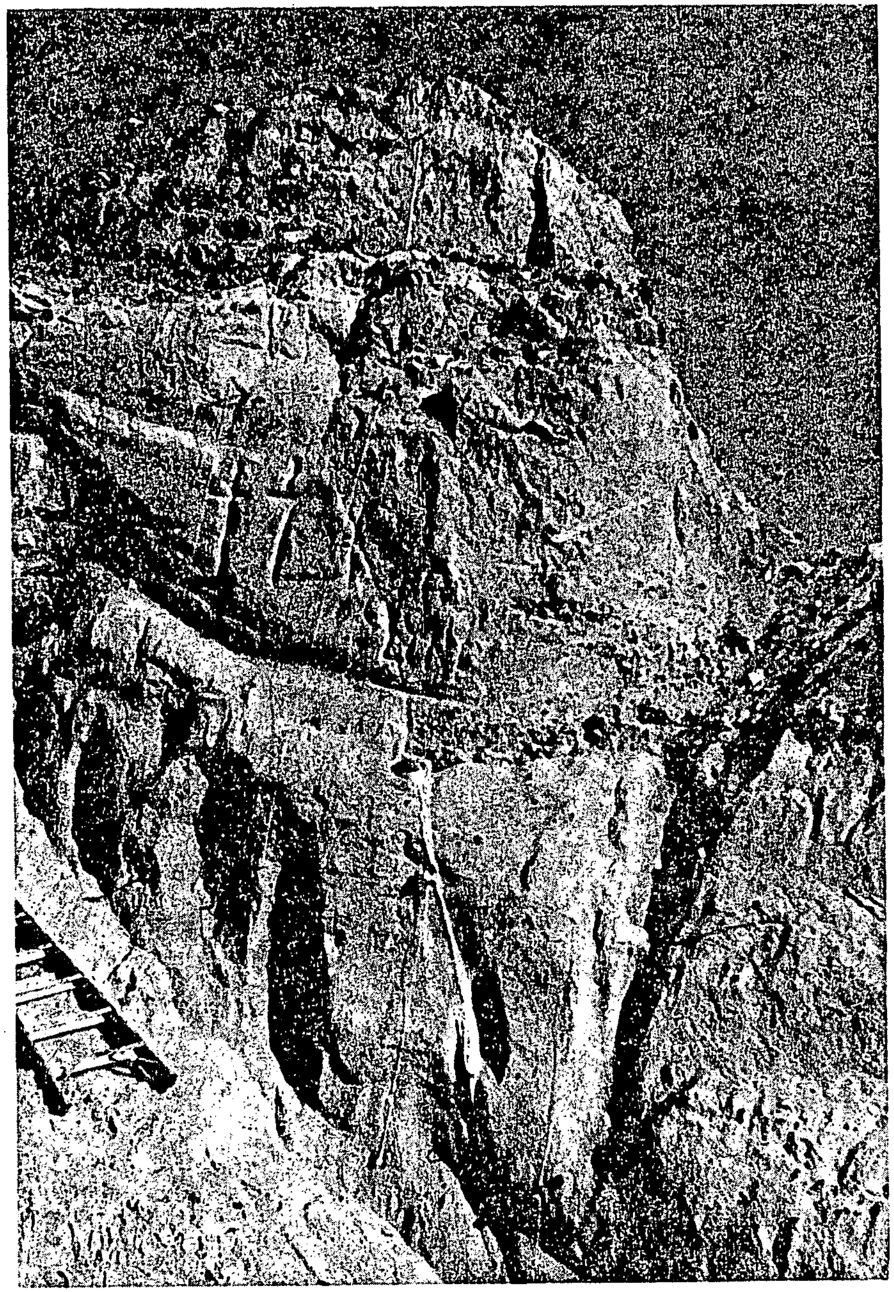

Figure 6
Landward or North Face of the Seacliff Expösure showing apparent fault.

Figure 7
Shear Zone (A3) truncated by marine terrace (Qn).
Detailed view of Figure 1.

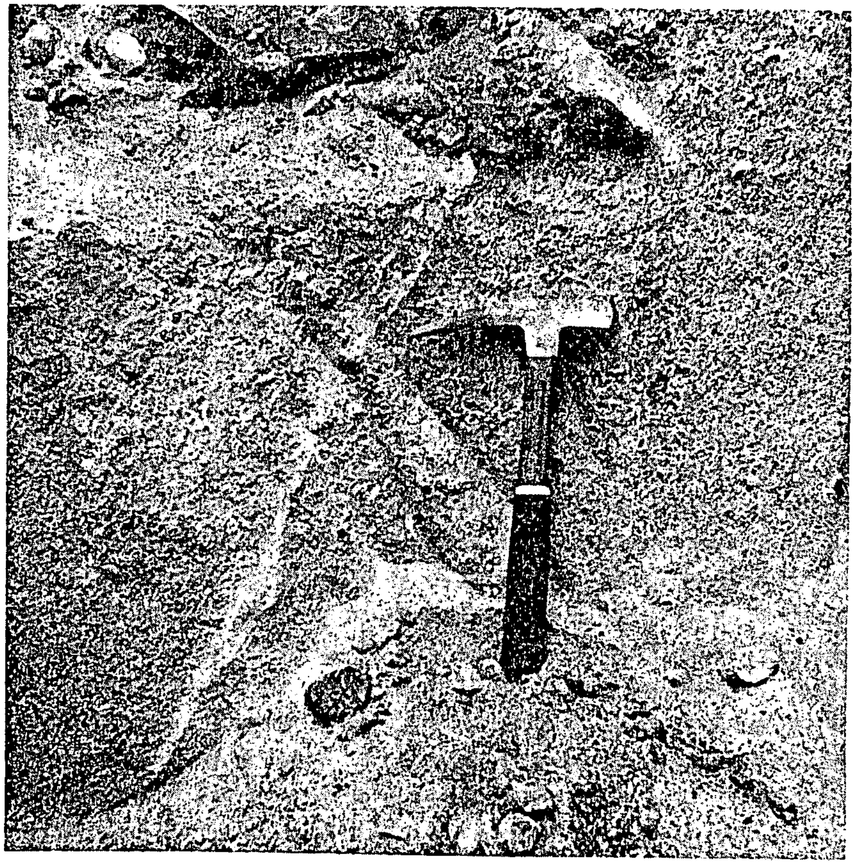

Figure 8
Shear Zone (A3) truncated by marine terrace.
South face of seacliff exposure.

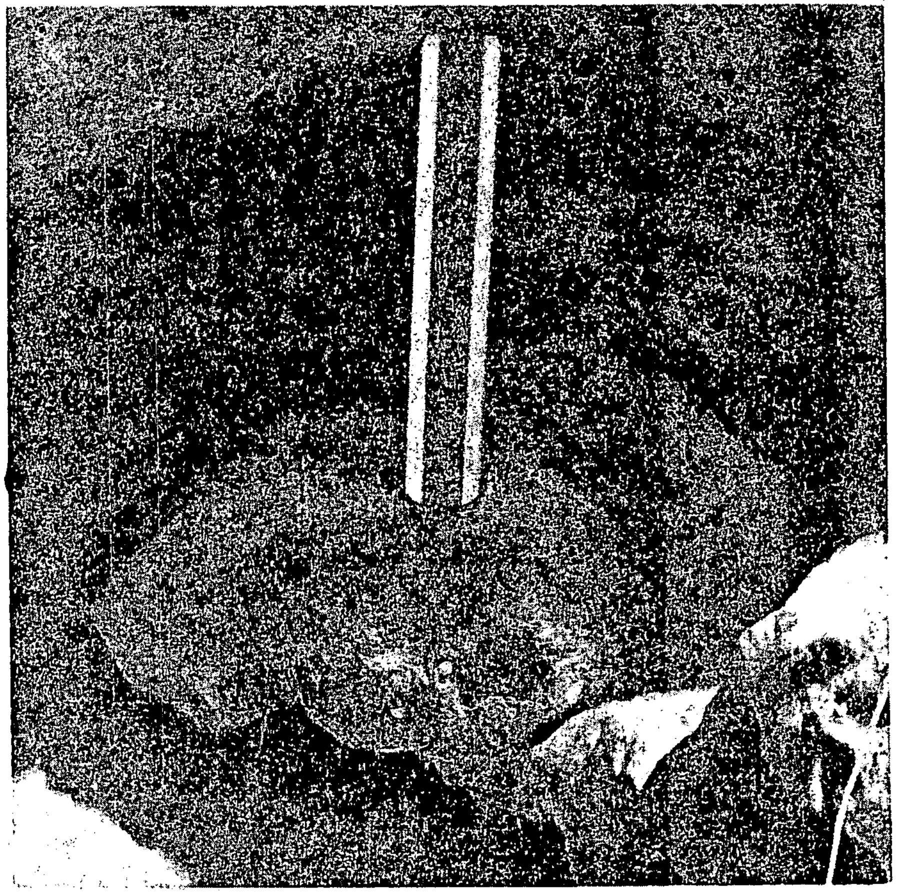

Figure 9
Clay silt inclusion in the San Mateo fm intersected by shear zone (A3). Exposure is in the seacliff directly below the exposure shown Figure 8. Nails mark trace of shear zone.

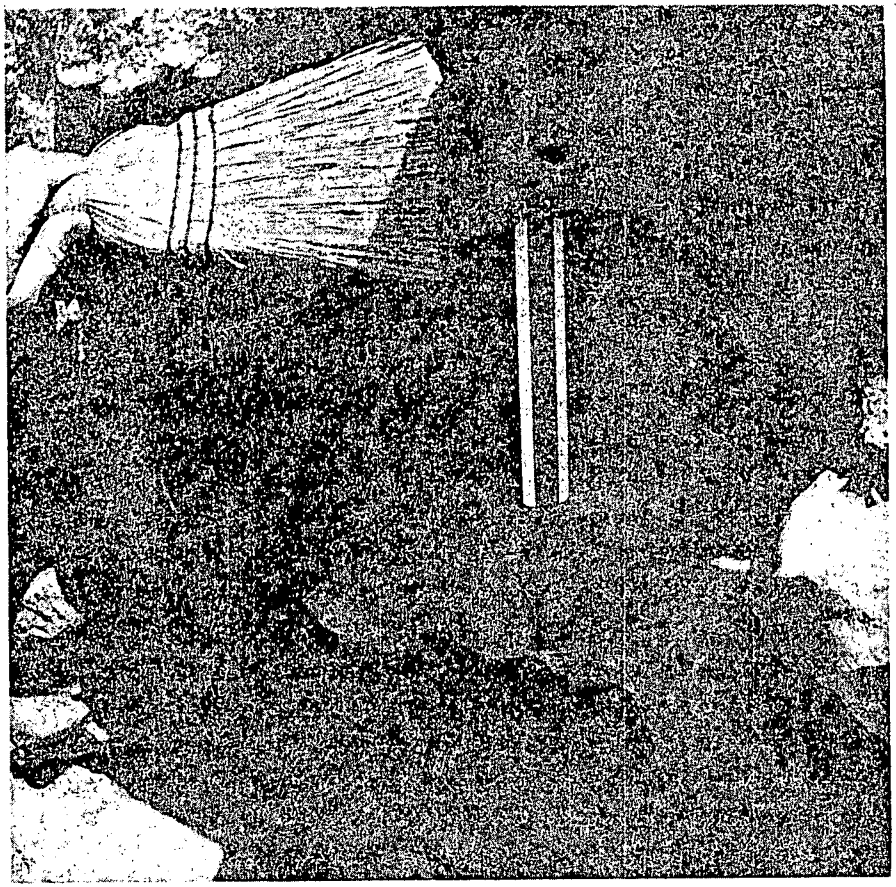

Figure 10
Clay silt inclusion in the San Mateo fm intersected by shear zone (A3), as in Photo 9. Showing lack of vertical offset.

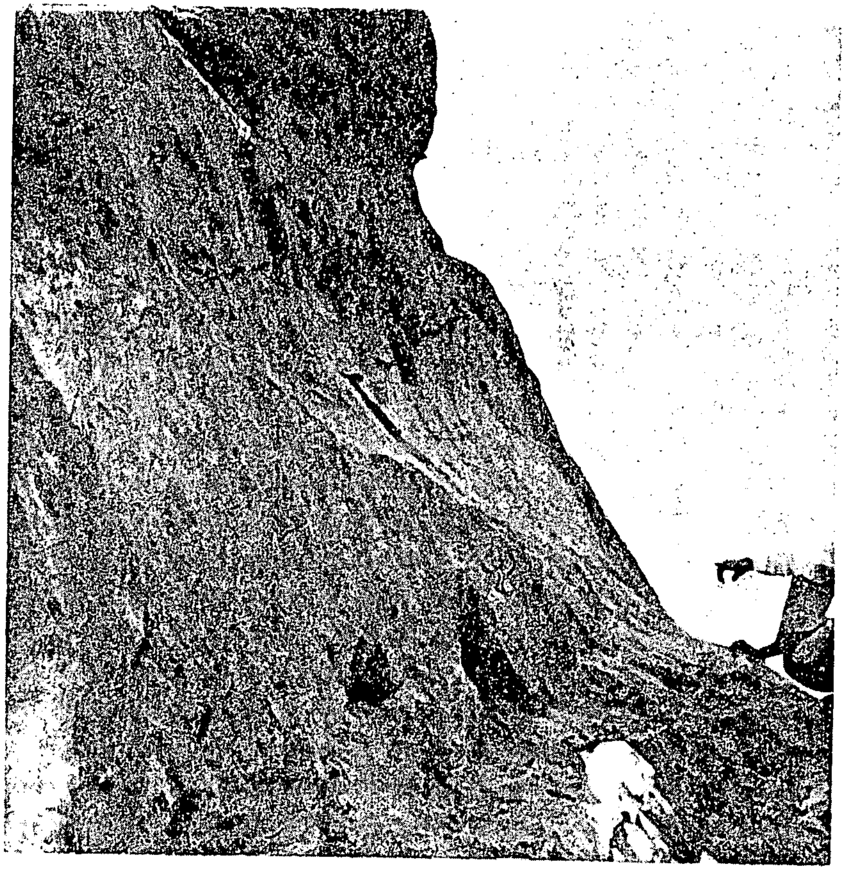

Figure 11
Face of erosional contact between the marine terrace and San Mateo Formation after excavation of the marine terrace materials.

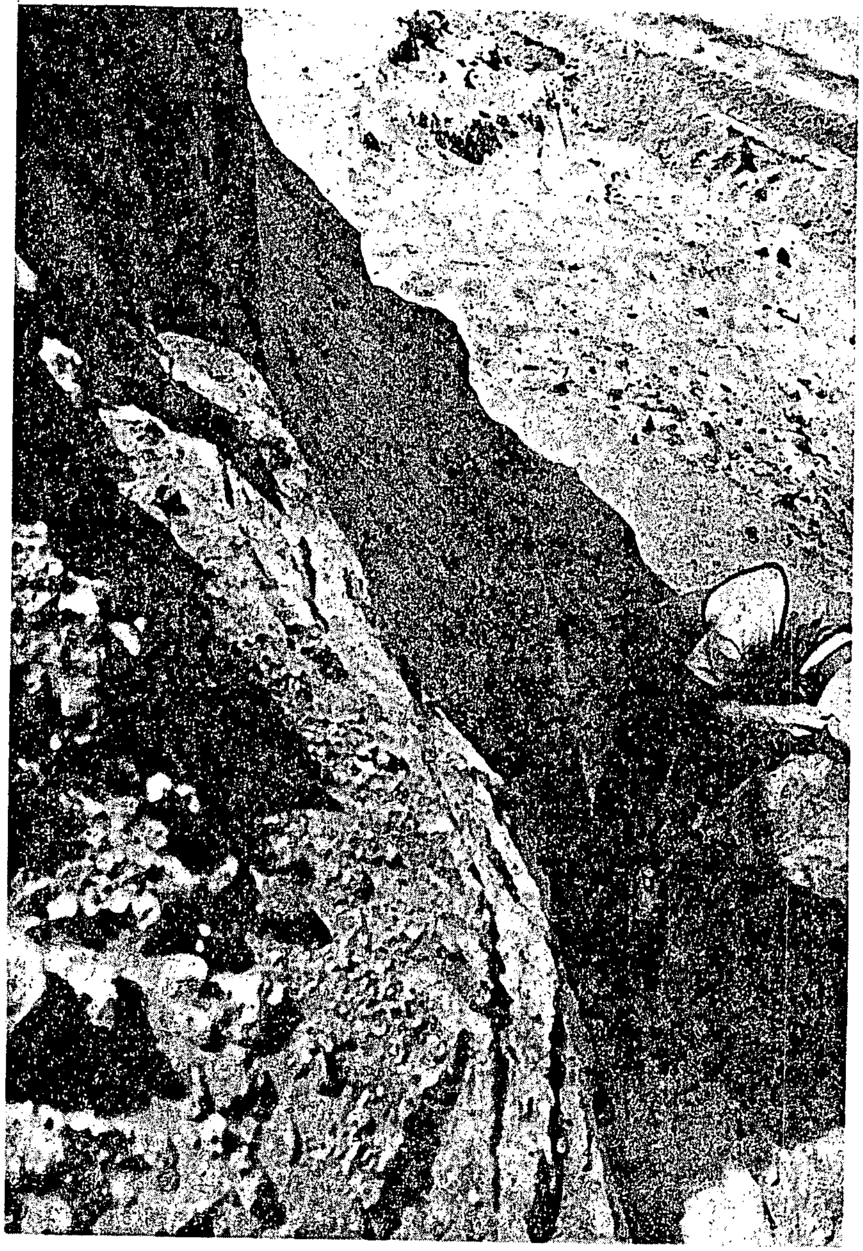

Figure 12
Trace of shear zone (A_3) at the feet of sweeper. The irregular surface to left of sweeper is the erosional contact of the marine terrace and San Mateo Formation.

APPENDIX A

United States Department of the Interior

GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

50-361
50-362

August 1, 1974

Mr. William P. Gammill, Chief
Site Analysis Branch
Directorate of Licensing
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Gammill:

Enclosed for your information is a draft review of the report "Analysis of Geologic Features at San Onofre Nuclear Generating Station" (AEC Docket Nos. 50-361 and 50-362). The review was prepared by Mr. F. A. McKeown and includes also the observations of Mr. R. F. Yerkes.

Sincerely yours,

Elmer H. Baltz
Deputy Chief for Engineering Geology

Enclosure

cc: J. F. Devine
R. H. Morris
W. V. Mickey

Draft
Frank McKeown
July 24, 1974

San Onofre Nuclear Generating Station
Units 2 and 3
AEC Docket Nos. 50-361 and 50-362

This is a review of a report entitled "Analysis of Geologic Features at San Onofre Nuclear Generating Station" dated July 5, 1974, and received by the U. S. Geolcgical Survey on July 11, 1974. The report was prepared by FUGRO, Inc., consulting geologists and engineers for the Southern California Edison Company. FUGRO prepared the report after investigations of some shear zones and sedimentary features exposed in the course of excavating the pad area for units 2 and 3. Comments based upon observations made by F. A. McKeown and R. F. Yerkes of the U. S. Geological Survey are included in this review. F. A. McKeown visited the site on June 11, 1974, and R. F. Yerkes visited the site on July 15 and 16, 1974.

The report prepared by FUGRO Inc., includes a brief history of the discovery of the shear zones and sedimentary features, a synopsis of the stratigraphy and structure of the site, detailed description of the shear zones and sedimentary features, a brief discussion of the results of their investigations. The report also includes 27 drawings, one table, and three appendices. In general, the documentation and analysis presented in the report are well done and we concur with the overall conclusions. However, some minor discrepancies are in the report and some data pertinent to the interpretation of the apparent offset terrace deposits were omitted or not recognized. Reexamination of data in the Preliminary Safety Analysis Report (PSAR) also indicates that some data pertinent to the recent investigations were omitted or not recognized.

The most important parts of the report are the descriptions and analyses of the "planar features" exposed during excavations of the pad areas. In order to avoid ambiguity these features in this review will be called for what they are, namely shear zones. Although documentation and explanation of the shear zones are important, the apparent offset of terrace deposits at the sea cliff, which was the real cause for detailed investigations, is not explained adequately in the report. It is mentioned on pages 4 and 15 as erroneously appearing to be a fault, and illustrated in drawings 4 and 5. The specific reasons to deny the offset of the terrace deposits as being a fault are scant and obscure in the report.

The shear zones (planar features) are identified as type A which trend north to N 10° E, and type B which trend N 40° W to N 55° W. The A shear zones are vertical or dip steeply to the west or east, the B shear zones dip steeply to the southwest. The type A shear zones occur in 4 principal discontinuous strands that extend from the seacoast to where one of them disappears under terrace deposits at the north side of the excavation. The type B shear zones occur in 6 principal strands, all of which terminate to the southeast in the excavation; their northwestern extent is unknown, because they extend toward unit one, beyond the limit of grading. The zones range from less than an inch to as much as 10 inches in width, are bleached white and commonly occur as slight resistant ridges in outcrop. According to petrographic studies in Appendix A of the report the white color is due to angular fine-grained crushed material and "the cementation is the result of mechanical building of the closely packed fine-grained material." Type A shear zones consistently have left lateral displacement and type B shear zones consistently have right lateral displacement. Displacements on both types range from 0.5 to 4 inches. Where the two types of shear zones intersect they mutually offset each other.

A search for the northwestern extent of B type shear zones resulted in a discovery of several other occurrences of similar zones northwest of unit one. No displacement is reported for these occurrences and none was apparent to the reviewer. All were truncated by the terrace deposits. An investigation was made to determine whether shear zones or fractures similar to type A and B occurred outside of the reactor site. An abandoned quarry 1.7 miles northwest of the site and the sea cliff near San Onofre Beach were examined. Both localities had exposures of fractures or shear zones which were truncated by terrace deposits.

The origin of the shear zones is suggested from a "theoretical analysis" in appendix B of the report. Several origins were postulated but the one preferred is that the shear zones resulted from widespread northwest-southeast compressional stresses. This is a reasonable interpretation.

As mentioned in a previous paragraph description and explanation of the sea cliff exposure of apparent offset of terrace deposits is not treated adequately in the report. On page 4 of the report, the contact of the marine terrace deposits with the San Mateo formation is described as irregular and of erosional origin and that the sea cliff exposure shows a type A shear zone overlain by terrace deposits. This description is correct but incomplete. Examination of the photograph and sketch in drawing 5 does not convince the reviewer that terrace deposits are not offset aginst the San Mateo formation along shear zone A_3 (feature A_3). In fact, the sketch shows shear zone A_3 extending almost to the top of terrace deposits and separating them from the San Mateo formation. Zone A_3 is offset slightly at the base of the deposits; however, the small amount of offset could be of controversial significance. The important aspects of the information in drawings 4 and 5 relative to the interpretation of the apparent faulting of terrace deposits is left for the reader to deduce. The significant information in the figure that is not used in the text of the report is the stratigraphy. In brief, the sequence of stratigraphic units in the terrace deposits are not offset across the apparent shear zone. This information should have been described and utilized in the text.

Another important well-documented observation that is not specifically utilized in the report is that the displacement on A shear zones is only a few inches in a left lateral sense everywhere over hundreds of feet of exposure. This is completely incongruous with the apparent 10-11 feet of vertical displacement of the terrace deposits.

A discrepancy this reviewer notes is that the shear zone A_3 strikes N 38° W and dips 62° SE according to drawing 6. This strike and dip is assumed to be in error because the dip as plotted in the drawings is to the southwest and the strike is not compatible with trace of A_3 plotted in drawing 3.

Drawings 4 and 5 in the FUGRO report show 2 terrace (platform) levels. At the request of the U. S. Geological Survey on July 16, 1974, the elevation of the lower terrace was surveyed and found to be 38 feet above sea level. Elevations of bedrock in borings 1, 2, 3, and 4 (pl. 2-F, Append. 2B, PSAR) appear to be co-planar with the 38-foot platform at the seacoast. The profile (Drawing 6, Append. 2A) of the sea cliff in the PSAR however, indicates that the platform is about 42.5 feet in the vicinity of the exposure of A_3. Furthermore, only one terrace is shown in the profile. Within the limits of error of the drawings, the profile appears to show only the 46-foot terrace. This terrace had been assumed to be the lowermost one and correlative with a terrace about 4 1/2 miles northwest of the site, which has been dated at 70,000-130,000 years before present. The age of the 38-foot terrace therefore, is not known or else the correlation of terraces is in error. Considerably more detailed mapping of terraces from the dated terrace southeast to the site would be required to resolve the discrepancy in correlations and ages. It seems likely however, that the shear zones may be about 100,000 years old or older, because at no place do they offset the eroded surface of the San Mateo Formation.

In conclusion, the shear zones in the San Mateo Formation and that occur in the excavated area and vicinity of the site do not appear to be capable faults as defined in AEC criteria. Furthermore, the terrace deposits are not offset as they appear to be but were deposited against a steeply dipping erosional surface on the San Mateo Formation which may have been controlled by the shear zone in the formation.