REPORT ON LIMITED APPEARANCE OF MR. D. W. PHIFER
AND ALLEGED GEOLOGIC FEATURES,
CAMP PENDLETON, CALIFORNIA
JULY 29, 1981

SOUTHERN CALIFORNIA EDISON COMPANY AND
SAN DIEGO GAS AND ELECTRIC COMPANY

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INTRODUCTION

A limited appearance concerning geology was granted to Mr. D. W. Phifer on Thursday, June 25, 1981, as a part of the licensing proceedings on seismology and geology for San Onofre Units 2 & 3. This appearance was granted as a result of his allegation that "There are three major unreported faults on Camp Pendleton" (TR 1419:12,13).

In his limited appearance on Thursday, Mr. Phifer presented what he believed to be evidence for the faults listed below:

1) "San Onofre Mountain Fault"
2) "Horno Summit Fault"
3) "Horno Canyon Fault"
4) "Piedra de Lumbre Fault"
5) "Vandegrift Boulevard Faulting"

and on Tuesday, June 30, 1981, he stated that, in addition to those listed above, there are the:

6) "San Onofre Creek Fault"
7) "San Mateo Creek Fault"

The earthquake potential of the alleged features at San Onofre were noted in Mr. Phifer's limited appearance. As a result of Mr. Phifer's geologic interpretation, he speculates that "...we are looking at something between [M] 6.5 and 8. And my slight knowledge of seismicity tells me that's about 1g at the plant..." (TR 1426:18-20). The documentation for this allegation is absent.

In his statement, Mr. Phifer made reference to gravity and magnetic studies of the region by Dr. S. Biehler.

Mr. Phifer has not reached any conclusions about the data "...but then you never know about [Bouguer] gravity..." (TR 1429:6,7).

Subsequent to Mr. Phifer's limited appearance, field examinations were conducted by the Applicants on June 27, July 3, July 16, and July 17, 1981, to evaluate the geologic evidence for the alleged features. Mr. Phifer and Nuclear Regulatory Commission staff geologist, Mr. T. Cardone, accompanied the Applicants in the field on June 27, and July 17, 1981.

A discussion of the inspections and the conclusions reached are presented in the accompanying text.

The Applicants throughout the preceding decade conducted numerous geologic studies at the site (5-mile radius) and the area beyond a 5-mile radius to determine whether any major unidentified geologic structures were present that may influence the site geology. The following is a list of some of these investigations.

1) 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, by Converse, Davis and Associates, April 30, 1970.

2) Report of Geologic and Fault Reconnaissance, Vicinity of Oceanside, California, by Fugro, Inc., April 6, 1972.

3) Geomorphic Analysis of Terraces in San Juan and Bell Canyons, Orange County, California, by Fugro, Inc., September 16, 1975.

4) Generalized Subsurface Geological and Geophysical Study, Capistrano Area, Orange County, California, by Jack C. West, November, 1975.

5) Geologic Report on the Area Adjacent to the San Onofre Nuclear Generating Station, Northwestern San Diego County, California, by P. L. Ehlig, September 31, 1977.

6) Late Quaternary Evolution of the Camp Pendleton-San Onofre State Beach Coastal Area, Northwestern San Diego County, California, by R. J. Shlemon, 1978.

And the Nuclear Regulatory Commission staff posed several questions on the geology of the region. The response to those questions is presented below:

Response to NRC Questions, Question 361.5, November, 1977.

Response to NRC Questions, Question 361.6, September, 1977.

Response to NRC Questions, Question 361.7, September, 1977.

Response to NRC Questions, Question 361.8, December, 1979.

Response to NRC Questions, Question 361.9, December, 1979.

Response to NRC Questions, Question 361.10, December, 1979.

Response to NRC Questions, Question 361.13, December, 1979.

Response to NRC Questions, Question 361.16, November, 1977.

Response to NRC Questions, Question 361.27, November, 1978.

Many reports and maps by other investigators have been reviewed in the course of preparing the Final Safety Analysis Report (FSAR) and Responses to NRC Questions. These are listed in the FSAR.

In his limited appearance, and later comments, Mr. D. W. Phifer speculated that there are seven "new" faults in the region. From these he assigned a range of magnitudes with corresponding ground motion at the site. And he inferred that there is perhaps an alternative interpretation for the gravity and geomagnetic data. These inferences are addressed in the sections that follow.

The geologic maps by W. R. Moyle, Jr. (1973) are used as an index (Plates 1 and 2) and a circle is drawn around the locality where the fault characteristics are alleged to be present. Detailed maps present geologic information for selected localities. Photographs of particular features accompany the text and maps.

"HORNO SUMMIT FAULT"

As postulated by Mr. Phifer, the "Horno Summit fault" is a single continuous feature trending southeastward for a distance of 16 miles from San Mateo Creek, about 4 miles inland from the coast, across Camp Pendleton toward a series of faults mapped by Moyle along Vandegrift Boulevard. His evidence for such a throughgoing fault includes:

(1) A fault exposed in a cut slope at the northeast corner of Rifle Range 214,

(2) The juxtaposition of Cretaceous sandstone of turbidite origin on the east against massive Eocene sandstone on the west at Rifle Range 214, and at Horno Summit Ridge, a mile to the southeast,

(3) An apparent 200-foot vertical displacement with the east side down of a resistant sandstone bed south of San Mateo Canyon and an apparent discontinuity in the outcrops of the same bed near Las Pulgas Ammunition Dump,

(4) Faulting of San Onofre Breccia against Eocene sandstone in the area between Aliso Canyon and Las Pulgas Canyon,

(5) Faulting exposed on Vandegrift Boulevard and in Lawrence Canyon, at Oceanside, and

(6) The presence of San Onofre Breccia material just south of San Mateo Creek about two miles from the nearest outcrops of breccia.

Based on the occurrence of breccia material near San Mateo Creek, Mr. Phifer interprets his "Horno Summit fault" as a right lateral fault with a possible lateral offset of 20 miles.

The evidence for the hypothesized "Horno Summit fault" is discussed below by area starting at San Mateo Canyon on the northwest and proceeding southeastward to the feature exposed in the bluffs at Vendegrift Boulevard. This is followed by a discussion of the significance of the San Onofre Breccia material observed by Mr. Phifer along the south side of San

Mateo Canyon. On the basis of the Applicants' findings, it is then concluded that there is no substantive evidence for a throughgoing fault along the trend of the hypothesized "Horno Summit fault."

Resistant Sandstone Near San Mateo Canyon

The Applicants' observations relating to the apparent offset of a resistant sandstone bed southeast of San Mateo Creek are essentially in agreement with the observations by Mr. Phifer. A resistant bed of quartz sandstone with a clay matrix forms a distinctive cap on a ridge on the northeast side of a tributary to San Mateo Canyon (Fig. 1). A similarly appearing resistant sandstone bed crops out on the opposite side of the tributary, 2,000 feet to the southwest. Geometric projections of the two beds indicate they have a vertical separation of about 300 feet with the northeast bed lowest. If the two beds are the same, a fault probably extends between them as conjectured by Moyle (1973). If such a fault exists, it is not a continuation of the Mission Viejo fault toward which it trends to the northwest because its east side would be down whereas the Mission Viejo fault is consistantly down on the west.

The Applicants cannot determine whether or not the above occurrences of resistant sandstone represent a single stratigraphic horizon. The resistant beds exposed at San Mateo Canyon, and a similar bed exposed in the vicinity of the Las Pulgas Ammunition Dump, appear to have formed by prolonged weathering under seasonally humid tropical or subtropical conditions. They are in essence an old paleosol (oxisol) developed on sandstone. Their resistance appears to result primarily from cementation by silica; locally pods of chert-like rock are present within it. The highly resistant layer is about 2 to 4 feet thick but is underlain by intensely weathered claystone having a moderate to low resistance to erosion. The limited outcrop distribution of the sandstone might reflect an originally discontinuous distribution of the sandstone or it might represent sandstone capping terrace remnants standing above an active floodplain. Thus, although this paleosol may have developed during a single time interval, perhaps simultaneous with the Claymont Clay Member of the Silverado Formation in the Santa Ana Mountains, it need not represent an initially uniform or continuous surface.

If a northwest-trending fault does exist between the two exposures of the resistant sandstone, the time of last displacement of the fault can be estimated by the continuity and age of well-preserved fluvial terrace deposits bordering San Mateo and San Onofre Canyons (Figs. 2 and 3). These terrace deposits are excellent stratigraphic markers that pass directly over or are projected across the fault as determined by instrumental hand-levelling and helicopter altimeter survey. The terraces are regionally extensive and traceable several miles along the larger drainages in the Camp Pendleton area, and thus apparently formed mainly because of Pleistocene climatic change rather than because of local tectonism. The age of the terraces can be estimated by correlation with world-wide sea-level fluctuations and by comparison of soil development.

A minimum age for possible displacement of the inferred fault is afforded by a well-preserved flight of fluvial terraces bordering the north side of San Mateo Canyon near Firing Range 313 (E 1/2, sec 32, T. 8 S., R. 6 W). Here some seven distinct fill terraces have been mapped at successively higher elevations (Fig. 1; Moyle, 1973); and helicopter reconnaissance and ground checks show the presence of at least two higher and older remnant surfaces.

The San Mateo Creek terraces are underlain by gravel fill, generally 20 to 25 feet thick. Except where cut by local sidestreams, most terrace fills are traceable a few miles upstream and downstream from the inferred fault.

Although not directly overlying the inferred fault, the second, third, and fourth San Mateo Creek terrace fills are traceable to within several hundred feet of the fault. Instrumental leveling (5-power Abney Level) shows only a normal down-gradient decrease in elevation (3-5 degrees) of terrace surfaces projected across the inferred fault. Likewise, within instrumental resolution (about 10 feet), helicopter altimeter settings on "matching" surface across the fault indicates no measurable vertical displacement.

The age of the San Mateo Creek terraces can be ascertained by association with climatically-controlled sea level change, and by comparison with dated, comparably-developed soil profiles near San Onofre. The lowest (youngest) regional terrace along San Mateo Canyon is not present in the inferred fault area. However, where observed downstream near San Mateo Road (sec. 6, T. 9 S., R. 6 W.; Fig. 1), this terrace bears at best only a weakly-developed soil profile (with possible cambic horizon). The terrace at this locality also projects into the subsurface, and is now buried by modern floodplain deposits of San Mateo Creek. It is thus likely that this lowest terrace fill was laid down mainly during the last major "pluvial" epoch about 17,000 to 20,000 years ago and is equivalent in age to channel deposits about 100 feet below present sea level near San Onofre (Shlemon, 1979, Figure 5a).

The age of the second terrace along San Mateo Canyon is estimated from its older stratigraphic position and its relative soil profile development. Reconnaissance indicates that the soil is well-developed and in general comparable with that described from the San Onofre Canyon area (Figs. 4 and 5). Accordingly, this terrace is estimated to be at least 35,000 to 40,000 years old.

The third highest San Mateo Creek terrace, approximately 100 feet above the floodplain, bears a very strongly-developed relict paleosol (Fig. 6). Some five feet of the B_2t (argillic) and B_3 horizons are still preserved in a roadcut near

Firing Range 313 (NE 1/4, sec. 5, T. 9 S., R. 6 W.). The antiquity of the soil is indicated by its dark red (2.5YR 3/4) subsoil (B_3) and the moderately-thick, continuous illuvial clay films on ped faces. From comparison with soils of similar development dated elsewhere in California, this terrace profile is judged to be at least 100,000 years old (isotope stage 5). The underlying terrace fill is therefore deemed to be in the order of about 125,000 to 180,000 years old (stage 6).

In sum, the second, third and fourth San Mateo Creek terrace deposits can be projected across the trend of the inferred fault. Within resolution of instrumental measurement, no vertical displacement is apparent. Judging from their continuity and the correlation of these deposits with regional climatic and sea level change, and from comparison of relative soil profile development, last displacement of the inferred fault at this locality took place prior to 35,000 to 40,000 years ago, and more likely well before about 100,000 years ago.

About 3 miles southeast of San Mateo Canyon the inferred fault would project through a flight of five distinct river terraces on the north side of San Onofre Canyon ("middle fork") (Fig. 2, secs. 14 and 15, T. 9 S., R. 6 W.; Moyle, 1973). The three higher terraces are locally eroded and do not extend sufficiently "downstream" for correlation across the inferred fault. However, the lower two terraces are continuous and unbroken where crossing its inferred trend and a small fault exposed in the bottom of a deep gully (Figs. 2 and 4).

Inspection of San Onofre Canyon banks and sidestream cuts shows that all terraces are underlain by at least 15 to 20 feet of gravels and coarse sands. The terraces are successively younger fill deposits rather than straths. Each terrace-fill was laid down by an ancestral San Onofre Creek, and later abandoned owing to regional, climatically-induced changes of sedimentation and base level.

An approximate age for the San Onofre Creek terraces can be estimated by correlation with Pleistocene sea level changes and by comparison of soil development with profiles near San Onofre site dated by absolute and relative techniques (Shlemon, 1978, 1979).

Deposits of the lowest San Onofre Creek terrace are approximately 20 feet thick where well-exposed about 3,000 feet upstream from the inferred fault. The deposits are about 50 feet above the present floodplain, and most likely were laid down during a "pluvial" epoch when sea level was lower and when stream competence was increased (Fig. 3). At a minimum, therefore, these lowest terrace deposits are dated as about 15,000 to 20,000, or 60,000 to 70,000 years old, equivalent in age to stage 2 or 4, respectively, of the marine isotope chronology (Shackleton and Opdyke, 1973, Shlemon, 1978).

A more accurate age estimate for the lowest terrace is afforded by the relative development of soil profiles. As shown in Fig. 5, the lowest terrace bears a strongly-developed soil about 5 feet thick. Particularly diagnostic of age are the dark red color (2.5YR 4/6-3/4), coarse angular blocky structure, and moderately-thick, continuous illuvial clay films on ped faces (Fig. 7). Compared with soils dated near San Onofre and elsewhere in mediterranean climatic regimes of California (Shlemon, 1978) this lowest terrace profile is judged to be at least 35,000 to 40,000 years old (stage 3).

The higher four terraces in this area of San Onofre Canyon are presently used as mortar impact ranges by the U.S. Marine Corps, and thus could not be examined in detail. However, brief field checks and helicopter reconnaissance indicates that soil profiles on these surfaces are likewise strongly developed. The underlying sediments are older and from stratigraphic position and development are deemed to be in excess of about 100,000 years old. Accordingly, because at least the two lower (younger) terraces of San Onofre Creek are traceable across the inferred fault, last displacement must have occurred before about 35,000 to 40,000 years ago, and likely more than about 100,000 years ago.

Rifle Range 214, Horno Summit Ridge and Adjacent Areas

At Rifle Range 214 the fault exposed in the cut at the northeast corner of the range strikes between N45W and N50W and dips 65 to 70 degrees to the southwest (Fig. 8). The fault is marked by about an inch of gouge. Slickensides are oriented in various directions but the most prominant ones trend down dip. Strata on the northeast side of the fault consist of interbedded sandstone and mudstone with most beds 1 to 3 feet thick. The sandstone beds are normally graded with coarse sand at the base and finer sand at the top. Exposures on the southwest side of the fault consist of coarse-grained cross-bedded sandstone mainly composed of quartz with some feldspar grains and granitic granules and pebbles. The exposed stratigraphic separation across the fault is about 30 feet (Fig. 9).

Reconnaissance in the vicinity of Rifle Range 214 indicates the strata exposed on either side of the fault are part of a single formation in which thick sequences of relatively massive sandstone and some granule-pebble conglomerate interfinger with sequences of interbedded sandstone and mudstone. Thus, the fault does not juxtapose strata of different formations and it need not have a displacement significantly greater than that exposed at Rifle Range 214.

During reconnaissance along the trend of this fault between San Onofre Canyon to the northwest and Basilone Road to the southeast only one apparently minor fault, oriented about N40W 80SW, was found in a gully 2,500 feet southeast of the fault at Rifle Range 214 (Fig. 8). The only other fault observed in this area is exposed in the cut slope 200 feet west of the southeast corner of Range 214 (Fig. 8). This fault is oriented about N48W 57NE and has a normal separation of about 10 feet with the east side down.

Along Horno Summit Ridge, southeast of Rifle Range 214, Mr. Phifer indicates that massive Eocene sandstone on the southwest is faulted against Cretaceous strata on the northeast. In contrast, the Applicants' observations indicate the contact is depositional in origin. The strata referred to as Cretaceous by Mr. Phifer are similar to strata exposed in the vicinity of Rifle Range 214 except that mudstone is more abundant and that many of the mudstone layers contain fossil root tubes and structures typical of bioturbation. The rock types and sedimentary structures within this formation are suggestive of deposition within a coastal floodplain with interfingering marsh, river, and estuary deposits. Based on our observations, it is probably correlative with the upper part of the Paleocene Silverado Formation of the Santa Ana Mountains. The massive Eocene sandstone referred to by Mr. Phifer appears to be correlative with the Middle Eocene Santiago Formation of the Santa Ana Mountains. Northwestward from Horno Summit Ridge, massive sandstone beds near the base of this formation form nearly continuous exposures on north-facing slopes. Based on these exposures, the base of the Santiago Formation conforms with bedding and is a depositional contact. Moyle (1973) mapped it as such except that he referred to the underlying Paleocene Silverado Formation as part of the pre-Tertiary basement complex with which he grouped strata believed to be Cretaceous.

There is intense alteration of strata at the top of the Silverado Formation in exposures on Horno Summit Ridge. Mr. Phifer indicates the alteration may be due to hydrothermal alteration along a fault. The Applicants see, however, no evidence of faulting at this location and suspect that the alteration is the result of prolonged weathering prior to deposition of the Santiago Formation. Regional relationships indicate a long time interval occurred between deposition of the two formations, probably as a result of eustatic lowering of sea level.

Southeast of where the contact between the Santiago and Silverado Formations crosses Horno Summit Ridge, there is a bowl-shaped hollow which was most likely formed by landsliding (Fig. 8). In exposures above the road along the western edge of this hollow bedding within the Santiago Formation is locally deformed and faulting is present. Although this deformation might be of tectonic origin, we favor a non-tectonic origin in view of its occurrence along the head of a landslide.

Resistant Sandstone Near Las Pulgas Ammunition Dump

In the vicinity of Las Pulgas Ammunition Dump there are extensive outcrops of the resistant sandstone similar to the previously described sandstone (paleosol) exposed in San Mateo Canyon (Fig. 8). Mr. Phifer's projection of his "Horno Summit fault" passes through this area. As mapped by the Applicants, the outcrops of resistant sandstone appear to define a relatively smooth geometric surface as portrayed by structure contours without evidence of fault offset. Thus, we find no evidence for a significant fault passing through this area.

Fault East of Las Pulgas Canyon

The northwest-trending fault along the contact between San Onofre Breccia and Eocene sandstone east of Las Pulgas Canyon was previously mapped by Moyle (1973). His map indicates the fault is 1-1/2 miles long with a normal depositional contact between the San Onofre Breccia and Eocene sandstone beyond either end of the fault. The geometry of the contacts, as mapped by Moyle, indicate the fault has a vertical separation of about 200 feet with the west side down.

Vandegrift Boulevard Structure

On the field trip of June 27, 1981, Mr. Phifer pointed out a feature exposed in the bluffs on the east side of Vandegrift Boulevard which he believed was an exposure of the continuation of his "Horno Summit fault" (Figs. 10, 11). However, the Applicants conclude it was most likely formed by landsliding in the San Onofre Breccia followed by backfilling of talus and slope wash against the steeply inclined head scarp of the landslide. The bluffs on either side of this feature consist of San Onofre Breccia which is composed of material derived from Catalina Schist and has well defined bedding inclined toward the south-southwest at an average dip of about 5 degrees. At the top of the bluffs the breccia is overlain by marine and stream terrace deposits consisting of dominantly granitic sand and gravel derived from the interior of the Peninsular Ranges via the Santa Margarita River. The terrace deposits are the source of the talus and slope wash observed within the feature. The Applicants conclude that this feature was most likely formed by the following sequence of events.

Subsequent to deposition of the terrace deposits, the Santa Margarita River eroded its existing channel west of the present position of Vandegrift Boulevard. At the same time, the small tributary canyon, forming the southern boundary of the feature, was deeply incised into the river bluff creating a steep south-facing canyon wall as it cut downward through the San Onofre Breccia. After the bottom of the tributary canyon eroded below the present level of Vandegrift Boulevard, a segment of the south-facing canyon wall failed by landsliding, perhaps as a result of undercutting of a weak layer within the south-dipping San Onofre Breccia. The failure created a steeply inclined arcuate scarp at the head of the failure within the San Onofre Breccia and probably a nearly vertical bank within the overlying uncemented terrace deposits. Following the failure, the terrace deposits above the head scarp proceeded to ravel and accumulate as talus and slope wash along the base of the landslide head scarp. Erosion of slide debris along the bottom of the tributary canyon probably caused periodic movement in the slide mass and resulted in downdropping and backward rotation of the rampart of talus and slope wash along the back scarp of the landslide. As seen today, the landslide appears to have been stable for a considerable length of time and is being modified by weathering and erosion.

The fault origin proposed by Mr. Phifer is inconsistant with the following observations:

1. The sand and gravel deposits juxtaposed against the San Onofre Breccia have a structure typical of talus and slope wash deposits. Although they are composed of the same material as terrace deposit overlying the San Onofre Breccia, their sediment gradation, distribution and internal structure is dissimilar to that observed in the terrace deposits. Therefore, they are not a down-faulted segment of the terrace deposits.

2. As seen in the bluff along Vandegrift Boulevard (Figs. 10 and 11), the contact between the San Onofre Breccia and the sand and gravel deposits dips nearly vertically at the top of the bluff but curves toward the south as it comes down the face of the bluff and would appear to approach the horizontal if projected southward to a depth of several feet below the road elevation. This apparent flattening at shallow depth is characteristic of landslides but not faults of tectonic origin.

3. There is continuity in the structure of the San Onofre Breccia exposed in the bluffs along Vandegrift Boulevard on either side of this feature with no evidence of disturbance by tectonic faulting.

Therefore, the Applicants conclude that this feature is not a tectonic fault.

San Onofre Breccia Near San Mateo Creek

The Applicants have examined the San Onofre Breccia material observed by Mr. Phifer in the area south of San Mateo Creek (Fig. 1) and conclude that it is quarry gravel transported to the site for surfacing of roads. The material consists of a few blocks of San Onofre Breccia, less than 2 feet long, located adjacent to roads surfaced with gravel derived from the San Onofre Breccia. Similar blocks can be found along gravel roads throughout Camp Pendleton. The San Onofre Breccia is quarried at the mouth of Piedra de Lumbre Canyon for use as road fill and road gravel. A small part of the quarry material remains as blocks too large for road gravel as can be seen at the Piedra de Lumbre quarry. The blocks of this size are normally pushed to the edge of the road during gravelling operations.

Conclusion

Mr. Phifer's basis for the "Horno Summit fault" is mainly conjecture without substantive supporting evidence. Minor faults are locally present along the hypothesized trend but there is no apparent evidence for a continuous throughgoing fault. Several features ascribed to faulting by Mr. Phifer have other origins. These include the feature along Vande-grift Boulevard, the distribution of resistant sandstone near Las Pulgas Ammunition Dump, the distribution of rock types and features along Horno Summit Ridge and the occurrence of San Onofre Breccia float south of San Mateo Creek. Mr. Phifer's suggestion of as much as 20 miles of right lateral displace-ment on the "Horno Summit fault" is speculative and contrary to the fact that bedrock formations and contacts are contin-uous across the hypothesized trend of the fault. Therefore, in the Applicants' opinion the hypothesized "Horno Summit fault" does not exist.

"PIEDRE DE LUMBRE FAULT"

This inferred fault was hypothesized as a southward extension of a fault mapped to the northeast of Piedra de Lumbre Canyon by Moyle (1973). As evidence in support of his hypothesis, Mr. Phifer indicates that coastal terrace no. 2 stands at an elevation of 300 feet on the west side of the Piedra de Lumbre Canyon but stands at only 200 feet on the east side along the narrow ridge between Piedra de Lumbre and

Las Pulgas Canyons. From this he infers that a fault trends southward from the mouth of Piedra de Lumbre Canyon with the east side of the fault down 100 feet relative to the west side.

The contention that the terrace no. 2 has been displaced by faulting is not valid because the terraces referred to by Mr. Phifer are not of the same origin. The terrace west of Piedra de Lumbre Canyon is of marine origin. In the vicinity of the 300-foot contour, this terrace is an erosional surface lacking marine deposits; however, within one mile to the west remnants of three separate marine platforms veneered by marine gravel deposits are present between the 200 and 400 foot contours. The ridge separating the mouths of Piedra de Lumbre and Las Pulgas Canyons is underlain by stream deposited sand and gravel. The crest of the ridge has an elevation of about 200 feet and represents a Late Pleistocene floodplain of the two adjoining canyons. The base of the stream terrace deposits is exposed in a sand quarry near the seaward end of the ridge (Fig. 12). Here, the base rests on a relatively smooth erosion surface standing at an elevation of about 100 feet. These stream terrace deposits are similar to those present at the mouths of many canyons along the southern California coast. They bear no direct age relationship with adjacent marine terraces and should not be correlated with them.

In addition, prior geologic mapping by Moyle (1973) and Ehlig (1977) show no evidence of a fault trending down Piedra de Lumbre Canyon. Thus the Applicants conclude the hypothesized fault does not exist.

<u>"HORNO CANYON FAULT"</u>

The presence of this fault is based upon Mr. Phifer's reinterpretation of the California Division of Mines Santa Ana Map Sheet (1965) by relocating an existing southwest-trending fault a few thousand feet northwest to lie along Horno Canyon.

Horizontal slickensides in San Onofre Breccia are found along the canyon wall in Horno Canyon about 1 mile inland from the old El Camino Real. Marine terraces on the west-facing flanks of San Onofre Mountain were interpreted to have been offset some 200 feet vertically and the faulting was thought by Mr. Phifer to be young.

Prior mapping by Dr. P. Ehlig (1977; Letter, September 18, 1979 attached) indicated the possible presence of a small fault along Horno Canyon based on the apparent misalignment of a tuff bed in the San Onofre breccia exposed on opposite sides of Horno Canyon. However, the marine terrace platform at Elevation 325 feet and the break in slope between the terrace platform and the ancient sea cliffs project across the canyon without being displaced (Fig. 13). Based on association with the marine isotope chronology (Shlemon, 1978) this platform is at least 300,000 years old. Thus, any fault present would not be capable.

"SAN ONOFRE MOUNTAIN FAULT"

This fault is inferred to lie along the northeast flank of the San Onofre Mountains and is the contact between Miocene San Onofre Breccia and Eocene strata. Its presence is speculated based upon the highly resistant San Onofre Breccia supporting a northeast-facing scarp, with the Eocene strata down-dropped and exposure of a purported fault sliver of Eocene sandstone within San Onofre Breccia at the fault contact in Horno Canyon.

Detailed mapping, however, by Dr. P. L. Ehlig in 1977 and subsequent field checks indicate the east-facing scarp is the result of major landsliding occurring in the Eocene strata. The San Onofre Breccia is very hard and resistant, resulting in a pronounced ridge line and landslide scarps (Fig. 14). The unconformity between the San Onofre Breccia and underlying Eocene sandstone is observed on a firebreak at San Onofre Mountain and trends southeast to a ridgeline northwest of

Horno Canyon and then is obscured by brush. At Horno Canyon Road, the sandstone which appears to be within the San Onofre breccia is actually immediately below the unconformity and is depositionally overlain by breccia.

In addition, the proposed sense of movement on the hypothesized fault does not agree with the stratigraphic relationship along it. The northeast-facing scarp along the hypothesized fault is used as evidence of downward displacement. If such a fault existed, San Onofre Breccia or younger strata should occur on the down thrown side. Instead, the oldest strata are exposed on the downhill side of the scarp. The existing relationship is characteristic of scarps of erosional origin but is contrary to the stratigraphic relationship for normal faulting where young rock should be seen on the downdropped block. Therefore, the inferred "San Onofre Mountain fault" is not a tectonic feature; but rather, a collection of geomorphic and sedimentary features misidentified as a fault.

"SAN ONOFRE CREEK FAULT"

In the area directly east of the Cristianitos fault where San Onofre Creek has eroded its canyon through San Onofre Mountain, Mr. Phifer hypothesizes the existence of a northeast-trending fault concealed beneath the alluvium in the bottom of San Onofre Canyon. His evidence for this fault, as understood by the Applicants, is the presence of a higher ridge crest on the southeast side of the canyon (elevation about 1200 feet) than on the northwest (elevation about 900 feet) and the narrow, steep-sided nature of the canyon.

San Onofre Canyon is narrow with steep-sided walls at this location because it passes through erosionally resistant San Onofre Breccia. The difference in the elevation of the ridge crest on either side of San Onofre Canyon is the result of differential erosion rather than faulting. The crest is close to the projected position of the unconformity between the easily eroded Monterey Formation and the underlying erosionally resistant San Onofre Breccia. Remnants of the basal part of the Monterey Formation are locally present near the ridge crest on either side of the canyon, as mapped by Ehlig (1977). The unconformity is oriented such that it is lower along the ridge crest to the northwest of San Onofre canyon, where it overlaps the base of the San Onofre Breccia, than it is to the southeast where it rests entirely on San Onofre Breccia. Based upon existing exposures, the unconformity at the base of the Monterey Formation and the unconformity at the base of the San Onofre Breccia both project across San Onofre Canyon without discernable offset.

The fact that San Onofre Creek cuts across the erosionally resistant San Onofre Breccia can be explained by normal erosional processes without resorting to a faulting hypothesis. The path of the creek was probably established when the creek was eroding through soft strata of the Monterey Formation. When erosion reached the base of the Monterey, the creek was superimposed across the top of the San Onofre Breccia. Continued erosion has cut the present canyon into the breccia.

Thus, there is no basis for the hypothesized "San Onofre Creek fault."

"SAN MATEO CREEK FAULT"

A fault has been postulated by Mr. Phifer to extend down the entire length of San Mateo Canyon from about the Cleveland National Forest to the ocean, a straight line distance of about 10 miles (see Plate 1 of Moyle, 1973). It is the Applicants' understanding that this hypothesized fault would trend essentially southwest from the upper part of San Mateo Canyon following the course of the present stream, turn almost due west at San Mateo Road (SW1/4, sec. 5, T. 9 S., R. 6 W.), curve slightly to the northwest where crossing the Cristianitos fault, then make a final, almost 90 degree turn back to the southwest before "exiting" into the ocean south of San Mateo Point. According to Mr. Phifer (oral communication, June 30, 1981), evidence for such a fault are slickensides and "incised meanders" in pre-Tertiary rocks at the head of San Mateo Canyon (NE1/4, sec. 23, T. 8 S., R. 6 W.).

Based upon the Applicants' field observation, there is no basis for hypothesizing the existence of a fault along the bottom of San Mateo Canyon; the orientation and characteristics of the canyon are readily explained by normal erosional processes without resorting to a fault hypothesis. The "incised meanders" occur in the basement terrane where granitic rocks intrude the Santiago Peak Volcanics as shown on the Santa Ana Sheet, California Division of Mines and Geology (1965). The grain of the rocks cuts across the trend of San Mateo Canyon in this area and the sinuous bends in the bottom of the canyon - "incised meanders" - are probably controlled by variations in the hardness of the rocks. Although slickensides are indicative of faulting, almost no movement is needed to produce them and they commonly occur along joints which have experienced a small amount of shearing movement.

Three lines of evidence indicate San Mateo Canyon is not controlled by faulting in the area shown in Fig. 1 and on Plate 1 and, in part, previously described in our discussion of the hypothesized "Horno Summit fault." These include:

1. A resistant sandstone bed (paleosol) exposed in the Paleocene Silverado Formation on the northwest side of the canyon appears to lie in the same geometric plane as a similar sandstone bed which caps a ridge on the southeast side of the canyon (Fig. 1). This precludes the existence of a significant fault trending along the canyon bottom between the two exposures of sandstone.

2. The bottom of San Mateo Canyon was originally as much as 1-1/2 miles further northwest in this area but has progressively migrated toward the southeast through time because of a bend in the canyon which directs the stream against the southeast side of the canyon. Thus, it would be fortuitous if a fault were present beneath the

existing canyon bottom. Evidence for this is provided by a flight of at least seven stream terraces arranged in a curved pattern on the northwest side of the canyon (Plate 1). The terraces form broad benches stepping down to the existing canyon bottom. On the other hand, the southeast side of the canyon has steep slopes rising to above the elevation of the highest terrace on the northwest side of the canyon. The steep slopes are the result of progressive undercutting at the base of the canyon wall as San Mateo Creek migrates southeastward. The asymmetry cannot be attributed to differences in resistance to erosion because the same rock types occur on both sides of the canyon.

3. To the northeast of the bend in San Mateo Canyon, about 1/2 mile northeast of Firing Range 313, paired terraces occur on opposite sides of the canyon about 100 feet above the present stream grade (Fig. 15). Instrumental hand-leveling across San Mateo Canyon at this locality reveals no measurable difference in elevation. These observations are also corroborated by identical helicopter altimeter settings for terrace remnants on either side of the creek. The unbroken San Mateo Creek terrace is the third regional fill above the floodplain (see discussion in "Horno Summit fault"); and, based on downstream continuity and soil development is judged to be on the order of at least 100,000 years old. This precludes the existence of significant faulting along the bottom of San Mateo Canyon in this area during the last 100,000 years and is supportive of the evidence presented in (1) above which indicates the bedrock is unfaulted in this area.

GEOPHYSICAL CONCERNS

Detailed analyses have been made of the Regional and Local Complete Bouguer Anomalies of the San Juan Capistrano area using both onshore and offshore data. These include regional and residual separations from the Complete Bouguer Anomalies as well as integrating recently obtained data with the pre-existing data base. All previously mapped major tectonic features (i.e., the Offshore Zone of Deformation, Whittier-Elsinore Fault, Cristianitos Fault) have readily identifiable gravity signatures. These studies do not indicate the existence of any new structures in the area.

Aeromagnetic data obtained from the Bureau of Land Management for the Santa Ana Sheet (scale 1:250,000) has been studied along with the magnetic data previously obtained by the Applicants for the onshore and offshore data in the vicinity of San Onofre Nuclear Generation Station. These data support the conclusions reached in Biehler (1975).

No new structures have been delineated.

CONCLUSIONS

Mr. Phifer has postulated a total of seven faults. Two of these features, the "San Onofre Mountain fault" and the "fault" at Vandegrift Boulevard, were found not to be faults but rather to be the result of landsliding. The "Piedra de Lumbre fault" was found not to be a fault, but an expression of depositional origin of the non-marine river sediments rather than be of tectonic origin. There are minor faults, but none are significant in the context of 10CFR100 Appendix A. The lengths and orientations of these features are such that, even if capability were assumed, they would not be significant to the project design basis.

As part of the geotechnical investigation of the SONGS site, photogeologic methods were employed to determine geologic structure in the site area including a large portion of the region to the north and east of the San Onofre Mountain area on Camp Pendleton. Based upon such investigation, including regional geophysical investigations, geologic mapping and review of pertinent geologic data, it was concluded that nothing of tectonic significance pertinent to San Onofre Units 2 and 3 seismic design exists therein. This conclusion has not been changed as a result of the field investigation of Mr. Phifer's speculated features.

Finally, based upon the above findings which establish the absence of capable faulting postulated by Mr. Phifer, it is concluded that a "...[M] 6.5 to 8.00..." event with a corresponding ground acceleration value of about "...1g..." as speculated by Mr. Phifer, has no factual basis and accordingly, has no significance relative to the seismic design of San Onofre Units 2 and 3.

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1979, Ehlig, P. L., Letter, September 18, 1979.

September 18, 1979

TO: J. L. MC NEY

FROM: P. L. EHLIG, Consulting Geologist

SUBJECT: Hypothesized Fault
Displacing Mappable
Tuff Bed at Horno Canyon

Hill wash by the heavy rains of the past two winters has exposed a mappable tuff bed in two places within the San Onofre breccia in areas where it was not previously mapped by Ehlig and Farley (1977). One location is on the east side of Horno Canyon about 500 feet northeast of the landward edge of the main coastal terrace (see attached map). The other location is about 1,000 feet further southeast of the northwest flank of an unnamed canyon. In my opinion, these two exposures represent the same tuff bed as was previously mapped at nine locations by Ehlig and Farley (1977). The nine locations are distributed in a near linear alignment over a distance of 2-1/2 miles in exposures just landward from the coastal terrace. The two newly discovered exposures are in a nearly straight alignment with five exposures previously mapped to the southeast, but are 400 feet northeast of a line drawn through the four exposures of tuff previously mapped to the northwest of Horno Canyon. In view of the fact that bedding within the San Onofre breccia maintains its regional trend across Horno Canyon, the misalignment of the tuff bed across Horno Canyon is most likely the result of displacement along a fault. The stratigraphic separation of the tuff bed across the hypothesized fault is about 260 feet with the northwest side up relative to the southeast side (based on a mean orientation of N48W 40SW for bedding and a horizontal separation of 400 feet).

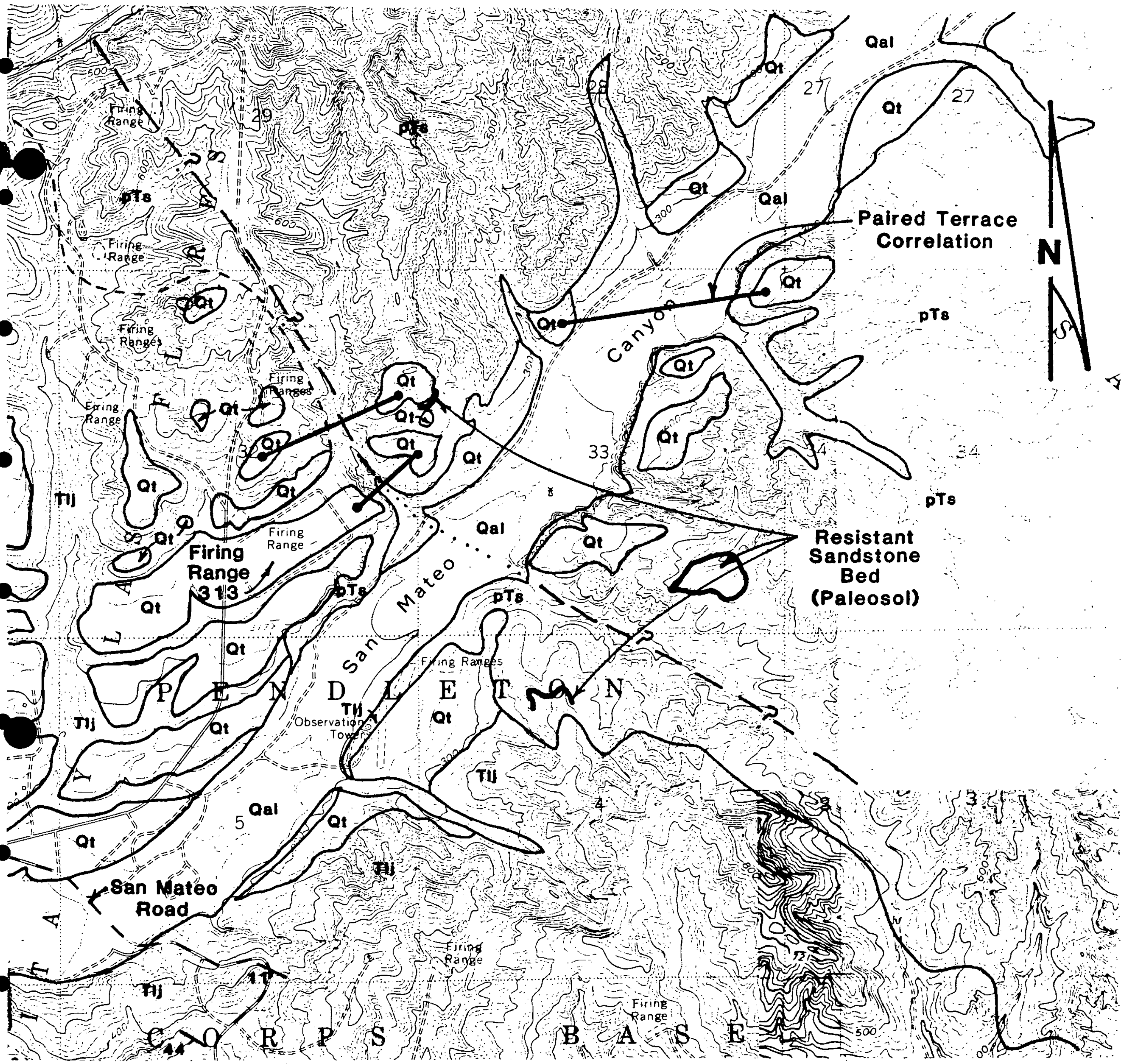
The hypothesized fault must be located in the interval of 1,100 feet between the tuff exposures on opposite sides of Horno Canyon. It could occur almost anywhere within this interval and could have almost any orientation. Alluvium conceals bedrock across most of the 1,100 foot interval. The alluvium is estimated to be as much as 60 feet deep and contains large blocks of Catalina schist that would be difficult to excavate if an attempt were made to locate the hypothesized fault by excavation of trenches or borings.

There is no evidence of offset of the Quaternary marine terraces which occur on either side of Horno Canyon in the vicinity of the tuff outcrops. Although the terrace shorelines bend in the area, they are not offset. The best example is the shoreline angle at an altitude of 325 feet. It is exposed about 600 feet on opposite sides of the canyon with no apparent offset. The wave cut cliff between the altitudes of 450 to 600 feet also shows excellent continuity across Horno Canyon.

On July 5, 1979, Mr. J. L. McNey and I spent the day doing reconnaissance in the Horno Canyon area searching for the hypothesized fault. Results of our investigation were generally negative. One fault was located which might account for the displacement of the tuff. It is exposed in the road cut on the east side of Horno Canyon about 1/2 mile up canyon from the displaced tuff bed. The fault strikes about N5E and is nearly vertical. Prominent slickensides plunge 6^{o} to the south. The groove pattern on the fault surface is suggestive of left lateral shear. The intensity of the shearing is suggestive of at least several tens of feet of displacement. The absence of mappable beds within this part of the San Onofre breccia prohibits the establishment of offset along the fault in this area. There is no evidence that the fault has experienced Quaternary displacement. Exposures are inadequate to permit the fault to be traced beyond exposures along the road.

In conclusion, the mappable tuff bed within the upper part of the San Onofre breccia is probably offset by a fault in Horno Canyon. The stratagraphic separation is about 260 feet. If such a fault exists, most if not all of its displacement predates the development of marine terraces overlying the tuff bed. The terraces are older than the coastal terrace which is known to be about 125,000 years old. Nothing observed by me is suggestive of an active fault in this area or one which is likely to constitute a risk to San Onofre Nuclear Generating Station.

FIGURE 1 San Mateo Canyon Drawing



SAN MATEO CANYON

See FSAR Figure 2.5-9 for explanation.

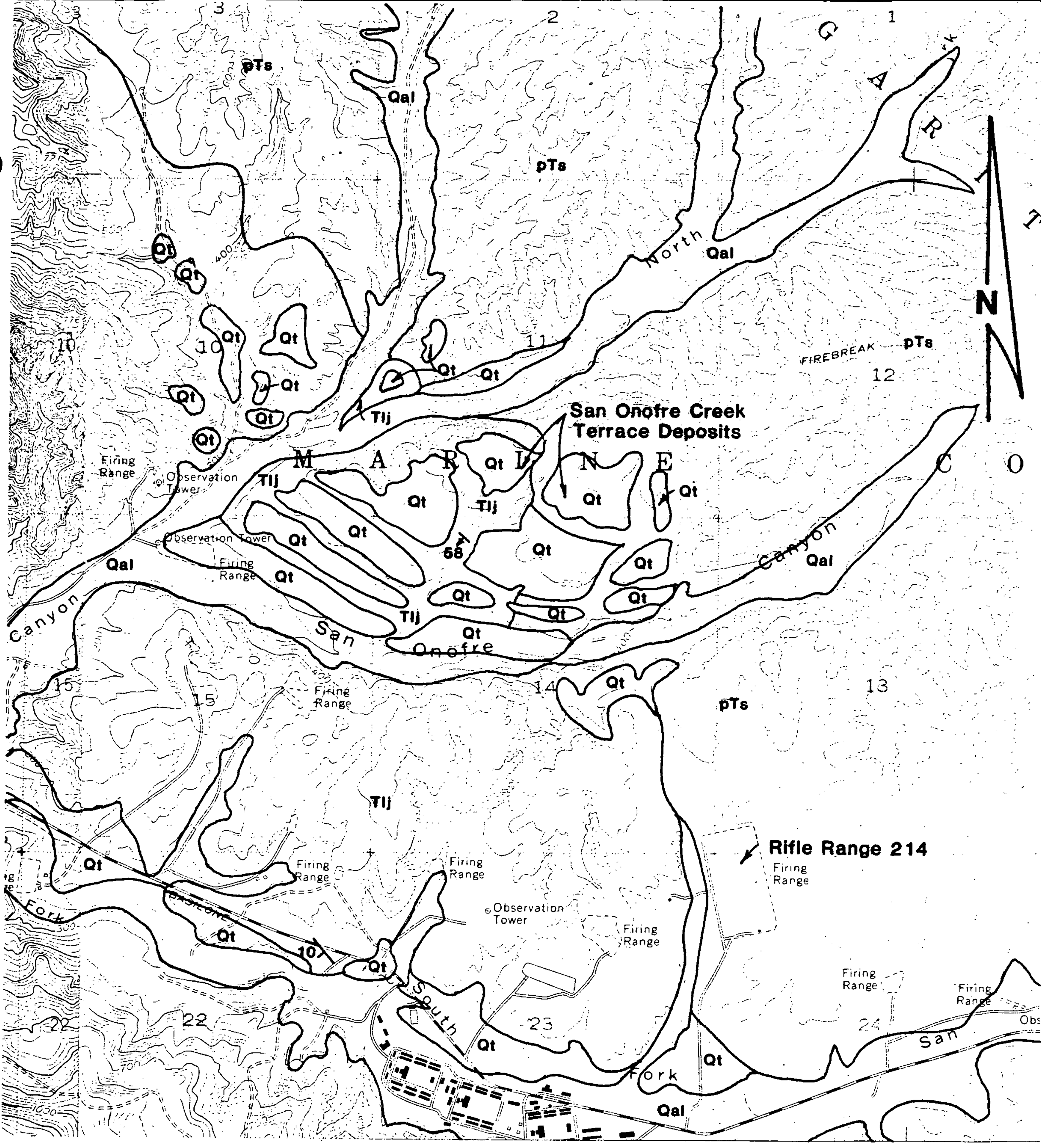
SCALE: 1:24000

●———● Indicates Paired Terrace Correlation

Fluvial terrace deposits (Qt) flanking San Mateo Canyon in the vicinity of Mr. Phifer's conjectured fault (after Moyle, 1973, Plate 1). Terraces more than about 100,000 years old project unbroken across the fault. Terrace deposits (third level), at least 100,000 years old and about 100 feet above the floodplain, are paired on either side of San Mateo Canyon precluding measurable vertical displacement along San Mateo Canyon.

Figure 1

FIGURE 2 San Onofre Creek Terrace Deposits Drawing



SAN ONOFRE CREEK TERRACE DEPOSITS

See FSAR Figure 2.5-9 for explanation.

SCALE: 1:24000

Fluvial terrace deposits (Qt) on the north side of San Onofre Canyon (after Moyle, 1973). The terraces range in age from at least 35,000 - 40,000 years (lowest) to well over 100,000 years.

Figure 2

FIGURE 3 Terrace Deposits, San Onofre Canyon

Terrace deposits, approximately 20-25 feet thick on north bank of San Onofre Canyon (NW 1/4, sec. 13, T. 9 S., R. 6 W.). Lowest terrace, approximately 60 feet above floodplain, bears an old, strongly developed soil (red area). This and higher (older) terraces cross unbroken over Mr. Phifer's inferred "Horno Summit fault" approximately 0.6 miles downstream (left).

FIGURE 4 Fault in San Onofre Creek Terrace Area

Faulting northward from Rifle Range 214 exposed in gully cut through overlying river terrace sediments. Note continuous terrace surface across fault trace.

FIGURE 5 Terrace Fill, North Bank San Onofre Canyon

Strongly developed, dark red (2.5YR 4/6-3/4) soil approximately five feet thick forming on lowest terrace fill, north bank San Onofre Canyon. Soil is at least 35,000 to 40,000 years old; underlying terrace fill is older (NE 1/4, sec. 13, T. 9 S., R. 6 W.).

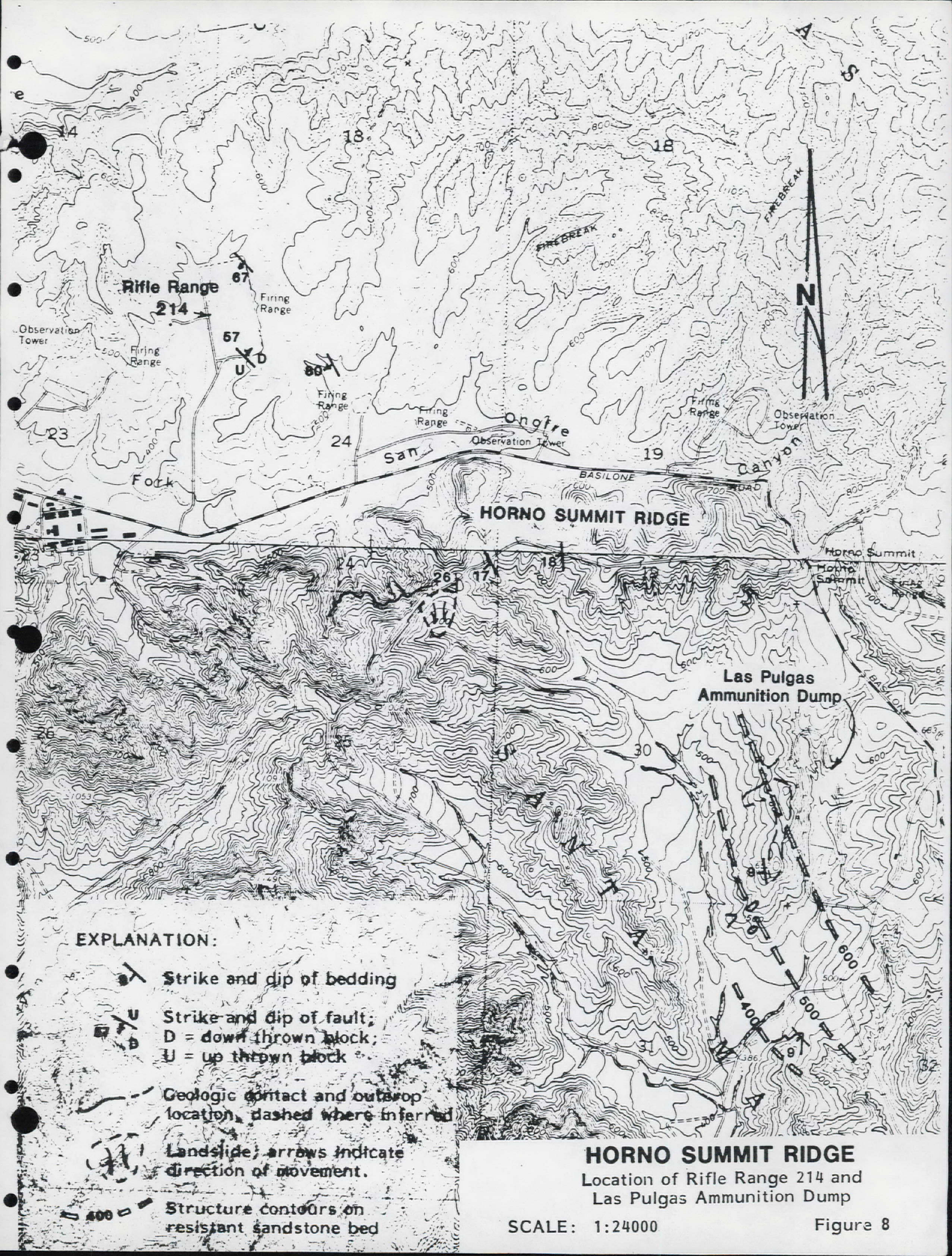
FIGURE 6 Strongly Developed Soil, San Mateo Canyon

Strongly developed soil on 15-20 ft-thick fluvial terrace fill near Range 313, northwest side of San Mateo Canyon. This terrace, at least 100,000 years old, is unbroken where projected across the trace of Mr. Phifer's inferred "Horno Summit fault." Projections of elevations across remnants of three older (higher) terraces also indicates no measurable tectonic displacement.

FIGURE 7 Angular-Blocky Ped

Strong, coarse angular-blocky ped from argillic (B2t) horizon of soil on lowest terrace crossing Mr. Phifer's inferred "Horno Summit fault," north bank San Onofre Canyon. Approximately 70 percent of ped faces are coated by moderately thick and continuous illuvial clay (cutans) attesting to antiquity of the weathering profile.

FIGURE 8 Horno Summit Ridge Drawing



HORNO SUMMIT RIDGE

Location of Rifle Range 214 and Las Pulgas Ammunition Dump

SCALE: 1:24000

Figure 8

FIGURE 9 Faulting in Rifle Range 214.

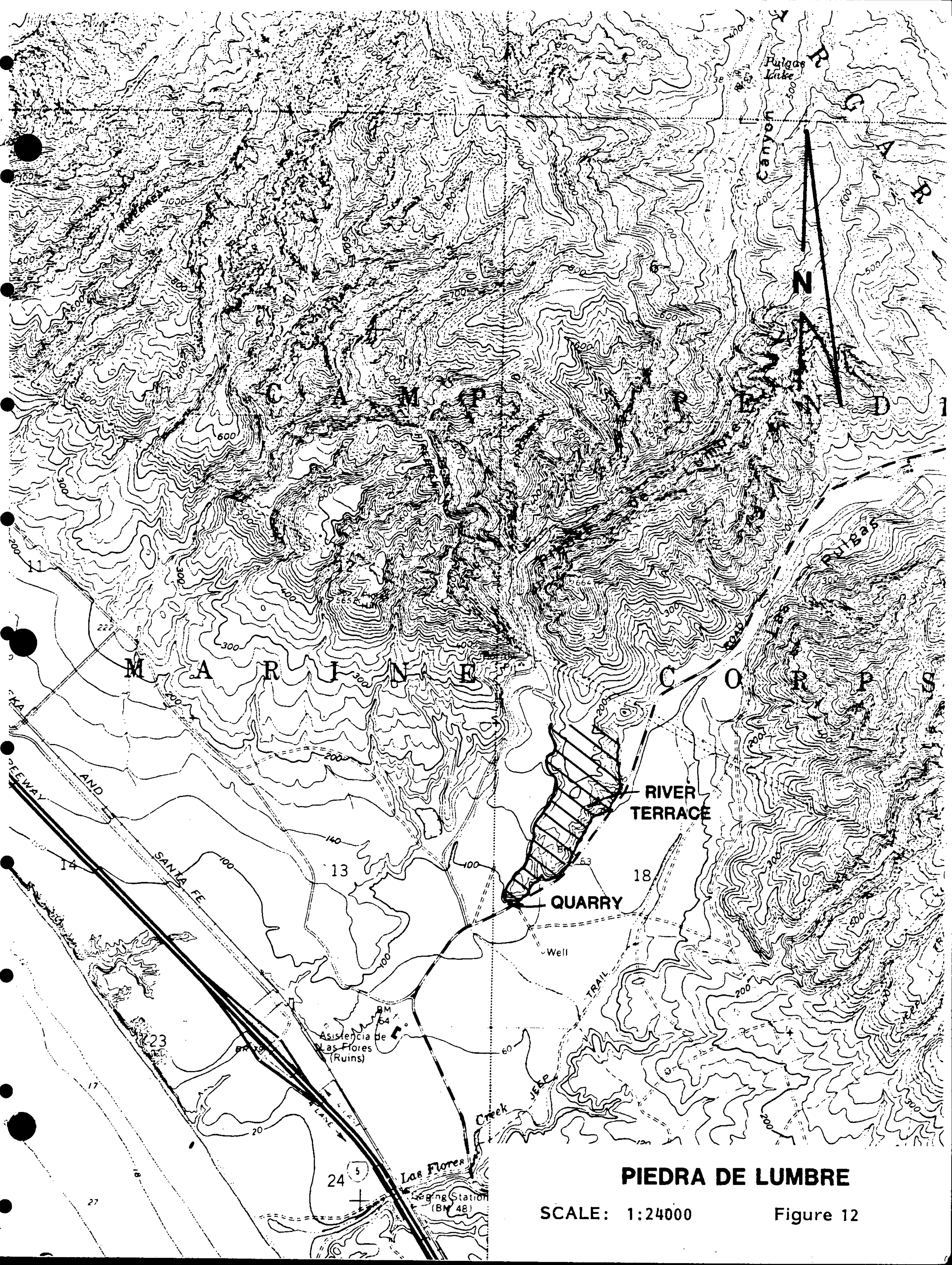
FIGURE 10 Vandegrift Boulevard Structure

Quaternary sands and gravels in landslide contact with San Onofre Breccia at Vandegrift Boulevard, Camp Pendleton.

FIGURE 11 Vandegrift Boulevard Structure

View looking northeast along Vandegrift Boulevard. Steeply dipping Quaternary sand and gravel with curved initial dip resting on landslide contact with San Onofre Breccia.

FIGURE 12 Piedra de Lumbre Drawing

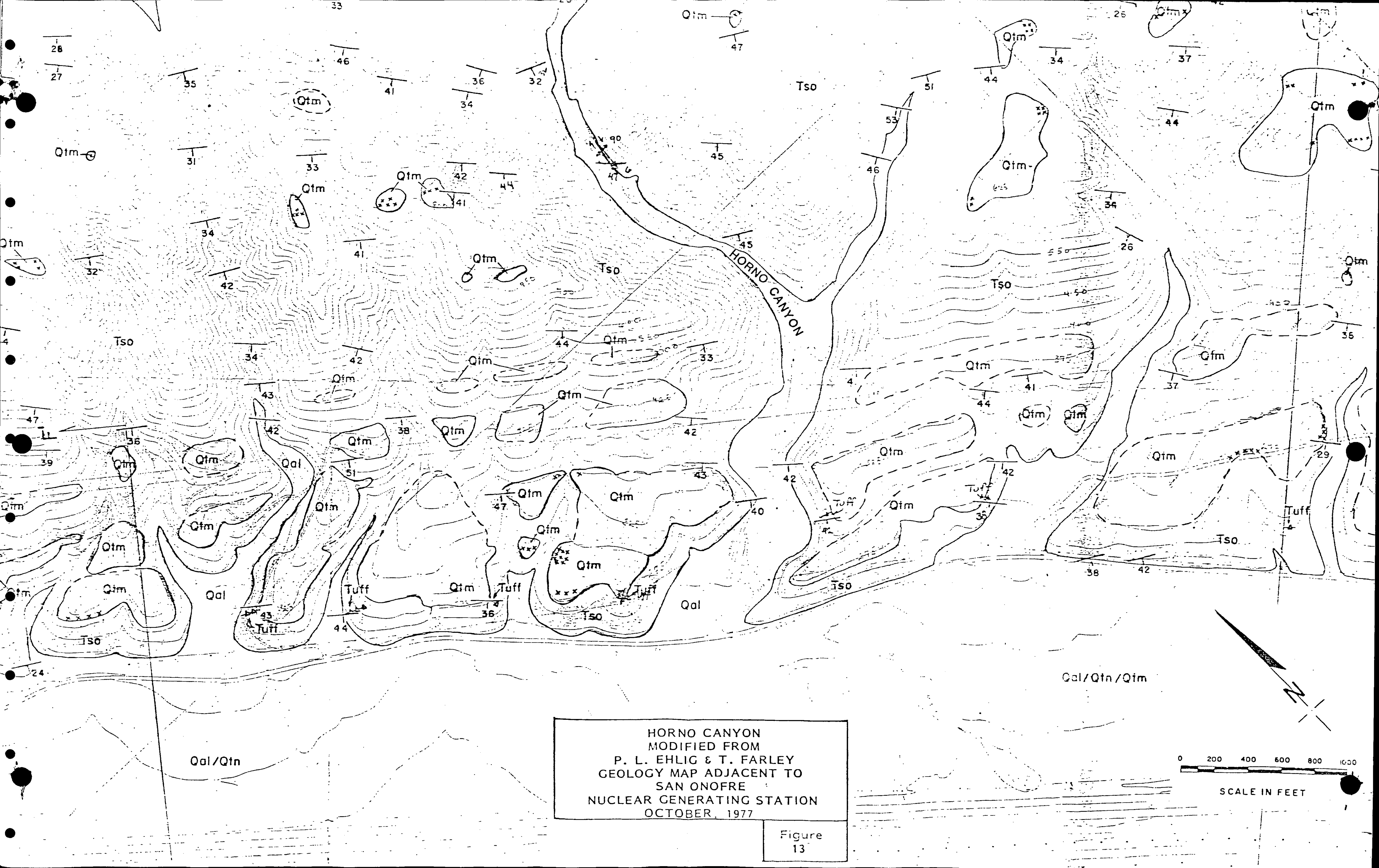


PIEDRA DE LUMBRE

SCALE: 1:24000

Figure 12

FIGURE 13 Horno Canyon Drawing



HORNO CANYON
MODIFIED FROM
P. L. EHLIG & T. FARLEY
GEOLOGY MAP ADJACENT TO
SAN ONOFRE
NUCLEAR GENERATING STATION
OCTOBER, 1977

Figure 13

FIGURE 14 Landsliding creating scarp on horizon along Mr. Phifer's alleged "San Onofre Mountain Fault."

FIGURE 15 High Level Terrace Fill, San Mateo Canyon

High level terrace fill, approximately 15-20 feet thick, southeast side of San Mateo Canyon (NE 1/4, sec. 33, T. 8N., R. 6 W.). Surface is about 80 feet above floodplain and occurs at same elevation as more continuous paved terrace on north bank of canyon creek. Geomorphic position, terrace elevation and continuity, and relative soil profile development attest to a minimum age of about 100,000 years for paired terraces either side of San Mateo Creek.