2C GEOLOGY & SEISMOLOGY

187

8004090 562

APPENDIX 2C

GEOLOGY & SEISMOLOGY

1.0 GENERAL

The proposed Rancho Seco Nuclear Power Plant will be constructed on the eastern side of the Sacramento Valley approximately 25 miles southeast of Sacramento, two miles east of Clay, California. The site covers approximately 2,480 acres in Sections 27, 28, 29, and 32, 33, and 34 of T.6N, R.8E in a rolling hill topography which varies in elevation from approximately 130 to 280 feet.

1.1 EXISTING BACKGROUND DATA

The first concentrated geologic effort within or near the site is described in the United States Geological Survey, Water Supply Paper No. 780 (1939) which covers the geology and water supply of the Mokelumne region. Subsequently, numerous papers - particularly those issued by the California Division of Mines and Department of Water Resources - have touched on various aspects of the local geology. Wildcat oil and gas wells in the surrounding area, drillers logs of water wells, and gravity survey data from a profile run nearby, have provided a major portion of the available subsurface information.

1.2 FIELD INVESTIGATION

Detailed geologic mapping was undertaken during 1967 to supplement published data. Subsurface exploration was undertaken to verify the three-dimensional relationships of the site area.

This subsurface exploration included: (1) the excavation of 22 backhoe trenches where natural outcrops were scarce; (2) the drilling and logging of twenty-eight 24-inch bucket auger holes, totaling 1,552 feet (generally, these auger holes were drilled to 70 feet unless special considerations dictated otherwise); (3) nine 4-1/4-inch drill holes, totaling 874 feet, for sampling and logging; (4) a core hole, 602 feet deep, was visually and geophysically logged and provided 23 representative core samples for laboratory testing for unconfined compression, absorption, porosity, and apparent and bulk specific gravity (following completion, this latter hole was tested for water quality and probable yield to determine its possible development as a water source for the plant and a piezometer was installed to provide for future water level measurements); (5) a shallow seismic refraction survey, covering three lines and totaling 11,550 lineal feet, to determine seismic velocities of the foundation material and depths to significant velocity layers.

183

1.3 CONCLUSIONS

a. The site is considered geologically feasible for development of the proposed nuclear facility.

b. Major shaking from distant earthquakes is not expectable.

c. No faults are known to exist within the area investigated and surface displacement is not expectable.

d. No subsidence problems are anticipated.

e. Subsurface structure in the Mehrten Formation within the site area is a gently dipping homocline. The general dip is less than 3 degrees to the west.

f. Unconsolidated materials are generally shallow, and easily removable.

g. All foundation materials would be readily rippable, and blasting would be unnecessary.

h. The water table (piezometeric surface) in the deep core hole (DH-23) is 143 feet below the ground surface. Potable water in quantity sufficient for limited use is available from the main aquifers in the Mehrten Formation at depths of 230 to 350 feet.

i. Laboratory analysis has indicated a horizontal to vertical permeability ratio of approximately 1000 to 1; groundwater contamination, therefore, should pose no problems.

2.0 REGIONAL GEOLOGY

2.1 GEOMORPHIC HISTORY

The geomorphic provinces of California and the general location of the Rancho Seco Site are shown in Figure 2C-1. The Coast Ranges, Great Valley and Sierra Nevada provinces are intimately related because of their geologic history and geologic structure.

In late Miocene time, sediments from the ancestral Coast Ranges were deposited in the sea and merged eastward to lap upon the gentle west-sloping volcanic plain.[1]

The Coast Ranges excluded the sea in early Pliocene time, forming an inland trough which was the ancestral Great Valley. The Sierra Nevada rose, and stream erosion began dissection of the recently formed Mehrten volcanic plain, coincident with the deposition of alluvial fans which eventually coalesced, and formed the Laguna Alluvial Plain. At the close of Pliocene

189

time, folding and faulting in the Coast Ranges deformed the sediments on the west side of the continental basin (Great Valley) but the Laguna Alluvial Plain remained intact. Continued uplift of the Sierra Nevada in the late Pliocene-early Pleistocene time caused stream entrenchment of the Laguna Alluvial Plain fanheads as the eastern margin of the Great Valley gently tilted westward.

Lateral erosion by the Sierra Nevada rivers in early Pleistocene beveled the earlier alluvial deposits and produced an even gravel-veneered surface, called the Arroyo Seco Pediment. In mid-to-late Pleistocene time, renewed uplifts of the Sierra Nevada caused accelerated stream entrenchment in the Sierra Foothills, dissection of the Arroyo Seco Pediment, and the formation of the Victor Alluvial Plain by coalescing alluvial fans. Subsidence in the Coast Ranges produced a low area that was inundated by the sea forming San Francisco Bay.

The rock types differ laterally and vertically. These differences result from the nature of alluvial fan deposition, dissection, and planation in which the stream courses and gradients change continuously as the alluvial fans and piedmont plains are built, incised, and built again.[2]

2.2 STRATIGRAPHY

2.2.1 Basement Complex[3]

The relatively complex regional stratigraphy of the basement rocks is pertimentent to this investigation primarilly by providing the background for dating the movement on the near-by Foothill fault system.

The western edge of the Sierra Nevada Province consists primarily of metamorphic rocks of Paleozoic and Mesozoic age which also form the basement rock beneath much of the Great Valley. These rocks nearly everywhere dip steeply and are essentially non-fossiliferous. In the southern part of the region the most extensive Paleozoic rocks are black carboniferous phyllite and schist with thinly interbedded meta-chert, but lenses of volcanic rocks and limestone are widespread and locally attain thicknesses of several thousand feet. In the northern part of the region, volcanic rocks, slate, and tuff constitute about equal parts of the Paleozoic section; chert is abundant locally but limestone is rare. Most of the Paleozoic rocks have been referred to as the Calaveras formation.

The Mesozoic section is characterized by alternating belts, each generally several miles wide, of volcanic rocks and sedimentary rocks, chiefly slate and graywacke. All the Paleozoic and Mesozoic rocks have been metamorphosed, but the metamorphism is of low grade in most of the region, particularly west of the Melones fault zone.

Ultramafic rocks, of which the most abundant type is serpentine, form elongate bodies within and adjacent to major fault zones of the region and they intrude both Paleozoic and Mesozoic metamorphic rocks.

190

The metamorphic rocks and serpentine have been intruded by a number of isolated small granitic bodies and by the Sierra Nevada batholith. Most of the bodies west of the Melones fault zone range from gabbro to quartz diorite.

2.2.2 Sedimentary Series[4]

On the east limb of the synclinal trough forming the Central Valley of California, overlying the bedrock which forms the base of the trough, is a thick sequence of marine and continental deposits ranging in age from Cretaceous to Recent. The Cretaceous and Tertiary deposits form a wedge of sediments that is thickest beneath the central portion of the Valley and thins to the east along the Sierra Mountain front.

The Quaternary sediments lie upon the Tertiary rocks and also thicken westward. The Tertiary rocks within the area generally appear in a somewhat orderly succession of roughly parallel north-south belts or zones. The sediments generally become consecutively younger westward and form a series of plains along the flanks of the mountains. The Quaternary sediments, the bulk of which lie west of the exposed Tertiary rocks, occasionally form finger-like tongues with apices extending eastward along the contributing streams across the dissected Tertiary plains. Sediments of the upper Tertiary and Quaternary periods underly the Rancho Seco site.

2.3 GEOLOGIC STRUCTURE

In gross terms, the Great Valley wedge of sedimentary rocks fills a structural depression between two elevated blocks of the earth's crust, the faulted and folded Coast Ranges on the west and the uniformly tilted Sierra Nevada on the east. (See reference 4). The Great Valley is an accumulation of sediments deposited in a trough that continued to deepen and developed a syncline whose axis lies on the west side of the valley. Along the axis, the sediments are over 30,000 feet thick but thin rapidly to the east where they lap upon the tilted block of igneous and metamorphic rocks which form the west flank of the Sierra Nevada. The formation of the Sierra Nevada during the Cenozoic Era differs from that of the Coast Ranges in that the Sierras tilted westward gradually as a single block, the active fault movement taking place along the eastern edge of the mountain block and near the axis of the Great Valley syncline (reference 2).

The faults that bound the Great Valley trend northwestward and are part of the geologic structural grain of California. (See Figure 2C-2). On the east side of the valley, the Foothills fault system is the major structural feature along the western flank of the Sierra Nevada as shown in Figure 2C-3. The faults in this pre-Cenozoic zone dip steeply, becoming vertical in some places, and transect Paleozoic and Mesozoic rocks which are in turn overlain by younger, unfaulted rocks. The closest of the Foothills' faults to the Rancho Seco site lies about 10 miles to the northeast. Faults of this system, which include the eastern Melones fault zone and the western Bear Mountain fault zone, truncate major folds and regional trends in the bedrock metamorphic rocks.[5]

Exposures of the Foothill fault system are bounded on the north and west by overlapping younger rocks. The system possibly extends beneath the valley fill and through the western Klamath Mountains into southwestern Oregon. Younger rocks conceal those cut by major faults for about 70 miles between the western Sierra Nevada and the Klamath Mountains.

Direct evidence of the direction and sense of movement along the Foothills fault system and individual elements is not readily apparent. Data suggests that the Foothills was a strike-slip system, i.e. primarily horizontal movement, but the direction of relative movement has not been determined.

It is probable that if displacement on this old system had amounted to only a few hundred or even a few thousand feet, at least its order of magnitude would already be known. It is possible that movement along the Foothills system, if it was a strike-slip system, totaled many tens of miles or more. Deep erosion since the latest significant movement of the Foothills faults has destroyed any physiographic evidence of the orientation and amount of movement.

The last movement of the Foothills fault system was in the late Jurassic age (135-plus million years before Present) as nearly as can be determined by current dating methods. (Figure 2C-4) The youngest rocks cut by the Melones fault zone (Mariposa Formation) are of about late Jurassic age and the youngest rocks cut by the Bear Mountains fault zone conformably overlie beds of probable latest Jurassic age. The Melones fault zone cannot be younger than middle Cretaceous, for south of Mariposa it is cut by a pluton that is presumably a lobe of the Sierra Nevada batholith. The above evidence indicates that no known surface displacement has occurred along the Foothills fault system in the last 135 (±) million years and can not have occurred within the last 100 (±) million years.

2.4 SUBSIDENCE

Surface subsidence has occurred at various location in the Great Valley and appears to be of three predominant types:[6]

a. Subsidence caused by lowering of ground water.

b. Near-surface subsidence caused by hydrocompaction (collapse of soil structure upon initial saturation).

c. Subsidence of the Delta near the confluence of the Sacramento and San Joaquin Rivers caused by compaction of peat deposits in old sloughs and tidal estuaries.

There has been no history of subsidence in the Rancho Seco area and the geologic investigations indicate that there are no conditions conducive to subsidence at the proposed site.[7,8]

2.5 SEISMICITY

The nearest active faults to the site are the San Andreas and Hayward Faults near the coast (89 and 70 miles to the west, respectively), and the Sierra fault, 80 miles-plus east, across the Sierra Nevadas.[9]

The seismic history of the region is discussed by Dr. Byerly in Appendix 2D. No active fault zones transect the Rancho Seco site (see Figure 2C-5). Seismic history reinforces this conclusion; there have been no earthquake epicenters recorded in the vicinity. Due to the nature of the bedrock and the distance from active faulting, the highest earthquake shock in the Rancho Seco site area has been of intensity V (Modified Mercalli Scale), as determined from the historic record. This includes the 1906 San Francisco earthquake (M 8.3) to the west as well as shocks from eastern epicenters (see Figures 2C-6, 2C-7, and 2C-8 Isoseismic maps).[10] Dr. Byerly reports that Sacramento has historically experienced shocks no greater than Modified Mercalli intensity VI. All information available indicates that earthquake shocks from epicenters located either to the east, west or south, are felt about one intensity lower at the site area than at Sacramento.[11,12] It is anticipated that intensity V is as great as will be experienced at Rancho Seco. Design for intensity VI will be definitely on the side of safety.

3.0 RANCHO SECO SITE

3.1 PHYSIOGRAPHY

The Rancho Seco site is on a broad, west sloping alluvial plain that has been constructed and dissected by many streams flowing westward from the flank of the Sierra Nevada. The elevation differential across the upland surface of the site is about 75 feet in 12,000 feet horizontal, a westward slope of slightly over thirty feet per mile. Near the site the alluvial plain varies in elevation from 280 to 205 feet and is roughly bounded by Hadselville Creek on the north and Dry Creek on the south. These two streams have eroded their channels about 100 feet below the west sloping upland surface. Further dissection by minor tributaries to the two main creeks occurs, although most of these minor drainages are intermittent and their courses are not deeply incised.[13] Locally, there are depressions one to two feet deep and 50 to 80 feet across and may be as much as 300 feet in the long dimension. These depressions are not "sink holes" and consequently have no subsurface structural expression.

193

3.2 INVESTIGATIONS

Field investigations began the last week in June 1967 and extended intermittantly through the first 3 weeks of August. Geologic mapping was undertaken, utilizing a small back-hoe to expose bedrock where natural outcrops were lacking. A total of 22 trenches were excavated to depths averaging 8 feet, logged visually, and backfilled. Surface outcrops were located and described and the information used to prepare the geologic map (See Figure 2C-9). Subsurface information was obtained from 28 bucket auger holes (24-inches in diameter) totaling approximately 1,552 feet, some of which were soil-sampled and all of which were logged geologically from the inside before being back-filled. The depth to which these holes were generally taken was 70 feet.

A rotary "portadrill" was used where laboratory soils samples were needed, since it was capable of drilling with air in dry to damp ground and utilizing drill mud when the ground became wet. Geologic logging of these holes was by visual examination of the cuttings and of the materials exposed in the ends of the soil sample tubes. These 4-1/4 inch diameter holes varied considerably in depth, depending on their location and purpose, but occasionally extended to 100 feet or over. Total portadrill footage was 874 feet.

A 6-1/4-inch hole was drilled to a depth of 602 feet to obtain geologic and seismic data on the deep foundation materials. This was to permit a realistic assessment of the formation response to seismic shaking and to attempt formation correlation with nearby wells. To this end, geophysical logs of all types were run in the hole in addition to visual logging (Figure 2C-10). Selected samples of core were taken for laboratory testing which included unconfined compressive testing, percent porosity and specific gravity determinations (Table 2C-1).

Upon completion of this hole, geophysical logs, including induction electric, self potential, density, sonic, gamma ray, sidewall neutron porosity (SNP) and a directional hole survey were run. A good water bearing interval was indicted in the 230-350 foot depth interval. A pump test was run to determine the feasibility of developing this nearby source for domestic water (See Hydrology and Groundwater, Section 2.4). The depth to groundwater at the site was found to be 143 feet in drill hole no. 23, within the well-consolidated Mehrten Formation. This is approximately 90 feet above the top of the best aquifers, however, as previously indicated.

Seismic refraction surveys were run along three lines totaling more than 11,550 feet to obtain subsurface velocities in the upper 200 to 300 feet beneath the ground surface (See appended geophysical report). Aside from providing additional data with regard to general foundation velocities, it was believed the Laguna-Mehrten Formation contact might be better defined by this technique (Figure 2C-11). Any large faulting of the rock not apparent at the surface would also have been detected if within the range of the survey.

TABLE 2C-1
DRILL HOLE 23 CORE ANALYSIS DATA

Lab No.	Hole No.	Depth	Rock Type*	Bulk Specific Gravity	Apparent Specific Gravity	Porosity (%)	Absorption (%)	Unc PSI	Remarks
-10	DH-23	95.0-95.8	Sandstone	1.201	2.024	40.6%	33.8%	216	#1 Sample Damaged in laboratory
-11	DH-23	97.2-98.0	Sandstone	1.247	2.265	44.9%	36.0%	136	
-12	DH-23	104.4-105.2	Sandstone/claystone bond	1.489	2.294	35.1%	23.6%	216	#3 Sample disintegrated in water
-13	DH-23	162.6-163.4	Sandstone	1.405	2.457	42.8%	30.4%	80	
-14	DH-23	164.0-164.8	Sandstone					128	
-15	DH-23	187.2-188.0	Sandy Claystone	1.381	2.338	40.9%	29.6%	192	
-16	DH-23	190.8-191.6	Sandy Claystone	1.493	2.408	37.9%	25.4%	128	
-17	DH-23	197.4-198.1	Sandy Claystone/small gravel center	1.312	2.389	44.9%	34.2%	216	
-18	DH-23	198.1-198.8	Sandy Claystone					144	
-19	DH-23	250.0-250.9	Coarse Grained Sandstone					816	
-20	DH-23	250.9-251.7	Coarse Grained Sandstone	1.795	2.586	30.5%	17.0%	936	
-21	DH-23	253.8-254.8	Sandstone	1.851	2.642	29.9%	16.1%	1264	
-22	DH-23	254.8-255.6	Sandstone	1.844	2.651	30.4%	16.5%	1168	
+-23	DH-23	256.1-257.0	Fine Grained Sandstone	1.645	2.631	37.4%	22.7%	352	
-1	DH-23	312.5-313.5	Sandstone	1.874	2.519			---	
-2	DH-23	313.5-314.6	Siltstone	1.856	2.000	25.7%	13.8%	104	
-3	DH-23	368.4-369.5	Siltstone	---	---	---	---	160	
-4	DH-23	461.0-461.7	Siltstone	1.613	2.133	23.7%	14.7%	1016	
-5	DH-23	461.7-462.5	Siltstone					680	
-6	DH-23	515.2-515.9	Siltstone	1.608	2.078	22.6%	14.0%	408	
-7	DH-23	515.9-516.6	Siltstone					328	
-8	DH-23	566.0-566.9	Siltstone	1.599	1.953	18.1%	11.3%	944	
-9	DH-23	566.9-567.8	Siltstone					832	

* Field Classification, + = Samples No. 1 and No. 23 utilized for Mechanical analysis

Mechanical Analysis % Sample Retained By Sive -	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	+200
Sample 1	None	0.92	12.74	25.39	24.57	21.52	7.99	6.49
Sample 23	None	None	No[illegible]	0.48	5.87	41.45	37.09	14.32

Due to the proximity of a 50,000-watt radio station (KRAK) which operates on a 24-hour per day basis except from midnight Sunday to 0500 Monday morning, conventional shooting techniques were considerably hampered. Dynamite caps were not safe on the site while the radio station was transmitting, so an 830 lb. weight dropping 8 feet was used to create the shock wave for approximately one third of the seismic lines run. The signal from the radio station proved so strong, however, that it obliterated some of the "thumper" records and conventional dynamite seismic methods during the unconventional morning hours had to be re-employed.

3.3 LITHOLOGY

The explorations revealed that, aside from Recent Alluvium (Qalo), three other surficial formations were present, i.e., Older Alluvium (Qalo), the Arroyo Seco Formation (Qas), and Laguna Formation (Tl). In addition, the deep hole (Drill Hole No. 23) also encountered the Mehrten Formation (Tm) at depth 126 feet and the Valley Springs Formation (Tv) at depth 350 feet. The lithologic character of these deposits is indicated in Table 2C-2.

3.4 STRUCTURE

At the proposed site, geologic structure is restricted to shallow bedding dips and erosional contacts. No faulting or folding of even small scale were observed in the mapping or subsurface exploration. As all the formations present are continental in origin and derived from the Sierra Nevada or its ancestral uplands, a generally shallow westerly dip of from 1 to 2 degrees prevails, although this is a locally masked by fluviatile cross-bedding and erosional channels.

3.5 ENGINEERING GEOLOGY

In the area of the proposed reactor buildings, the Laguna Formation is present beneath a veneer of clay-sand and residual gravel which forms the soil zone. The explorations indicate that the Laguna is generally firm siltstone, sand, gravel and conglomerate. Information on the physical characteristics of the upper 100 feet beneath the ground surface is presented in the accompanying detailed Geologic Logs of Drills Holes, or in Appendix 2E "Soil and Foundation Investigation Report." Only one hole, number 23, extended much below 100 feet. From this hole, 23 representative 4-inch diameter core samples from the depth interval of 95 feet to 567 feet were tested in the laboratory for unconfined compression, absorption, porosity and specific gravity. The results are presented in Table 2C-1. The apparent specific gravity column aided in defining the Laguna-Mehrten and Mehrten-Valley Springs contacts in drill hole number 23 due to the distinctly different lithology of the source material from which these formations were derived.[14,15] The variety of materials tested and their degree of induration varied sufficiently that only in a general way is the

TABLE 2C-2
TABLE OF ROCK UNITS

	Geologic Age	Formation and Symbol	Thickness In Size Area	Composition and Origin	Areal Extent	Engineering Properties
Quaternary	Recent	Recent Alluvium (Qal)	±0-5 ft	Stream deposited gravel, sand, and silt.	Confined to present drainage courses.	Unconsolidated, low velocity (<2,000 F.P.S.) easily rippable, dry.
	Recent Pleistocene	Older Alluvium (Qalo)	±0-10 ft	Old stream and terrace deposits of gravel, sand, and silt.	Covers flood plains in southwest portion of site.	Unconsolidated, low velocity (<2,000 fps) easily rippable, dry to slightly damp.
	Pleistocene	Arroyo Seco (Qas)	±0-15 ft	Deposits of well-rounded cobbles, pebbles and sand derived chiefly from pre-Cretaceous sediments on pediment surfaces.	Caps uplands in eastern portion of site.	Poorly consolidated, low velocity (<2,800 F.P.S.) easily rippable, dry to slightly damp.
	Pliocene	Laguna (Tl)	±126 ft*	Sand, silt, and some gravel; may or may not contain clay. Fluviatile deposits that are poorly bedded and poorly exposed. Non-andesitic in composition.	Predominant formation within the site. Major portion of excavation will be in this formation.	Friable to firm, locally very firm, low-medium velocities (<5,000 Fps) easily rippable, (predominantly horizontal) porosities range to 5%, upper 70 ft dry to damp.
Tertiary	Miocene	Mehrten (Tm)	±224 ft*	Fluviatile sandstone, siltstone, and conglomerate, dominantly of andesitic detritus. Locally contains horizons of coarse andesitic agglomerate of mudflow origin.	No surface exposures.	Firm to very firm, local moderate cementation, medium velocities (<4,500-6,000 Fps to ?); rippable, major aquifer, permeable (predominantly horizontal) 25-45% porosities.
		Valley Springs (Tv)	±252 ft*	Pumice and fine siliceous ash with much greenish-gray clay, and some vitreous tuff, glassy quartz sand, conglomerate; commonly well-bedded; derived largely from rhyolitic ejectamenta thrown out from the high Sierra Nevada.	No surface exposures.	Does not apply. (No excavation in this material is expected.)

*Measurements from Drill Hole 23

increase in unconfined compressive strength with depth apparent. Observations were made on the in-place Laguna Formation materials from within the 24-inch diameter bucket auger holes. Although friable beds were often in evidence, no materials were observed which caved or gave the appearance of caving, and the general condition noted was firm.

It is concluded that no faulting of the upper Tertiary and younger rocks has occurred at the site or in the surrounding area.

198

4.0 REFERENCES

1. Howard, A. D., "Development of the Landscape of the San Francisco Bay Counties", Geologic Guidebook of the San Francisco Bay Counties, California Division of Mines, Bulletin 154, pp. 96-106, (1951).

2. Taliaferro, N. L., "Geology of the San Francisco Bay Counties," Geologic Guidebook of the San Francisco Bay Counties, California Division of Mines, Bulletin 154, pp. 117-150, (1951).

3. Bateman, P. C. and Wahrhaftig, C., "Geology of the Sierra Nevada." Geology of Northern California, California Division of Mines and Geology, Bulletin 190, pp. 107-169, (1966).

4. Hackel, O., "Summary of the Geology of the Great Valley," Geology of Northern California, California Division of Mines and Geology, Bulletin 190, pp. 217-238, (1966).

5. Clark, Lorin D., "Foothills Fault System, Western Sierra Nevada, California, GSA Bulletin, Vol. 71, No. 4, pp. 483-496, (1960).

6. Poland, J. F., and Evenson, R. E., "Hydrogeology and Land Subsidence," Great Valley, California, Geology of Northern California, California Division of Mines and Geology, Bulletin 190, pp. 234-247, (1966).

7. "San Joaquin County Ground Water Investigation," California DWR Bulletin 146, p. 177, (1967).

8. Lofgren, Ben, Subsidence Related Ground Water Withdrawal in Landslides and Subsidence, Geologic Hazards Conference held in Los Angeles, California May 26 and 27, 1965, pp. 105-111.

9. Coastal Strain and Fault Movement Investigation - Faults and Earthquake Epicenters in California, DWR Bulletin 116-2, p. 96, (1964).

10. Report of the State Earthquake Investigation Commission, the California Earthquake of April 18, 1906, Vol. 1 and 2, Atlas, Carnegie Institute of Washington, (1908).

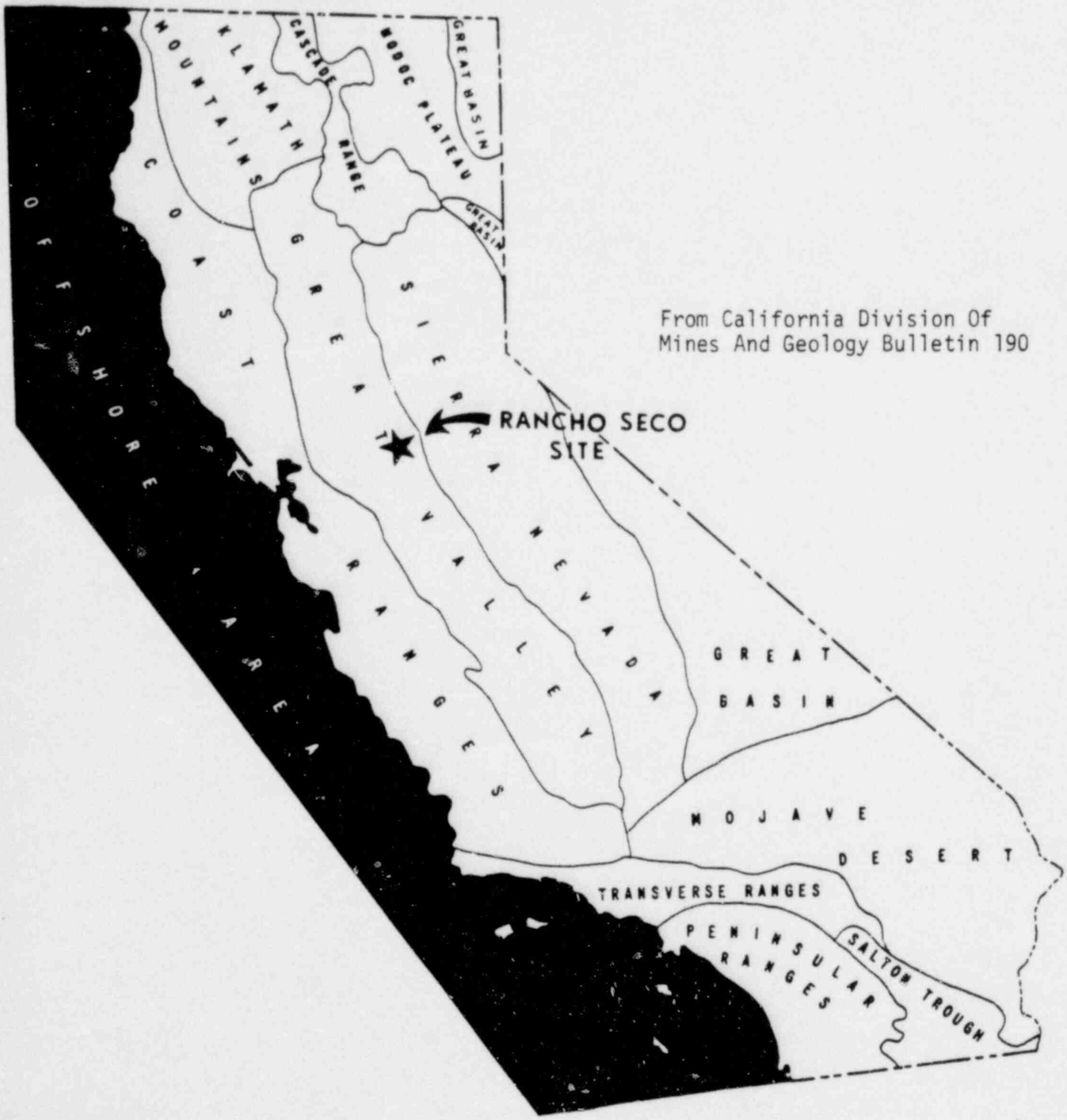
11. Cloud, W. K., "Intensity Distribution and Strong-Motion Seismograph Results, Nevada Earthquakes of July 6, 1954 and August 23, 1954," Seismology Association Bulletin Vol. 46, No. 1, pp. 34-40, (1946).

12. Neumann, F. and Cloud, W. K., "Strong Motion Records of the Kern County Earthquakes," in California Division of Mines Bulletin No. 171, pp. 205-210, (1955).

13. Piper, A. M. et al., "Geology and Ground Water Hydrology of the Mokelumne Area, California, USGS WSP 780, p. 230, (1939).

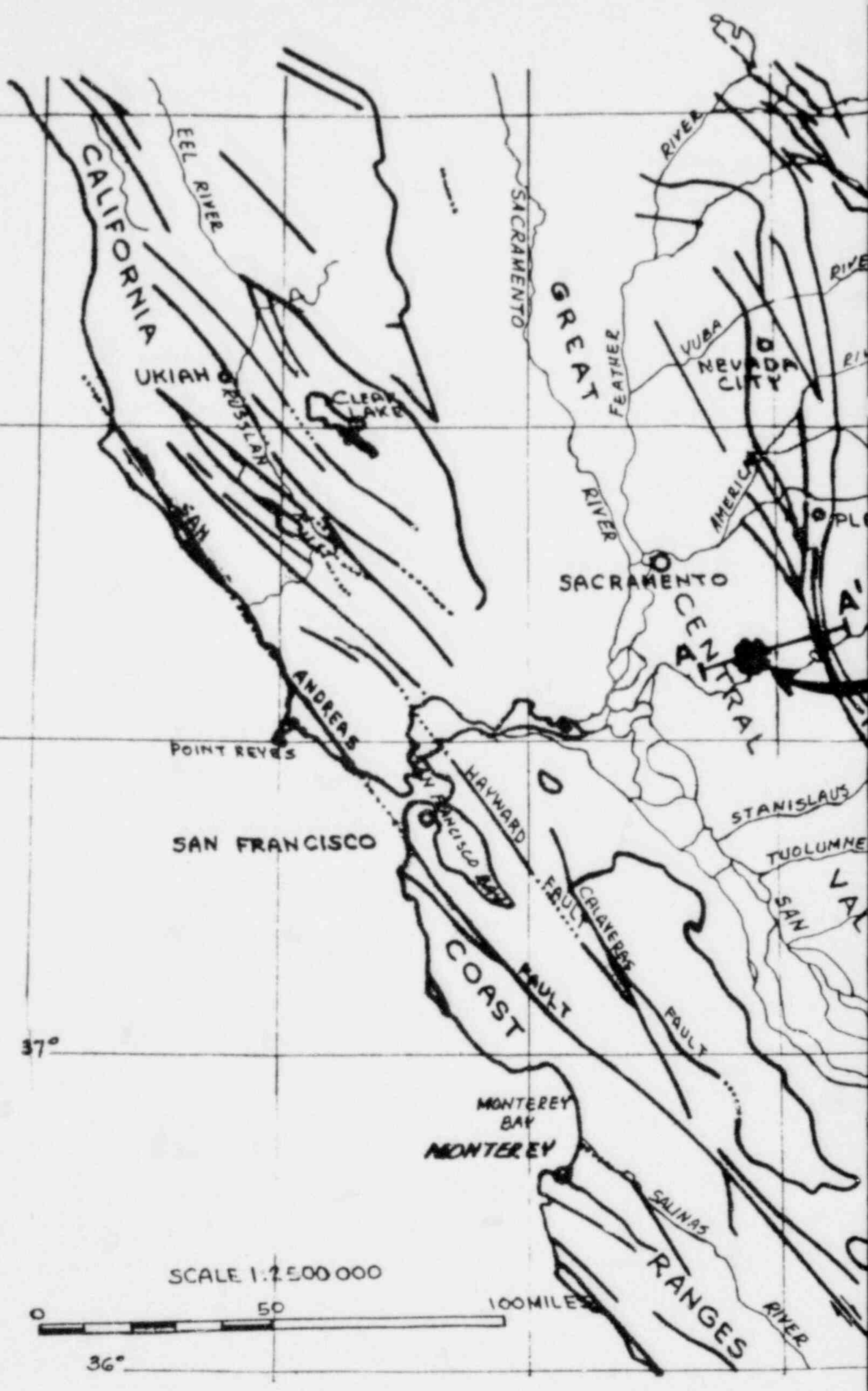
14. Slemmons, D. B., "Cenozoic Volcanism of the Central Sierra Nevada, California," Geology of Northern California, California Division of Mines and Geology, Bulletin 190, pp. 199-208, (1966).

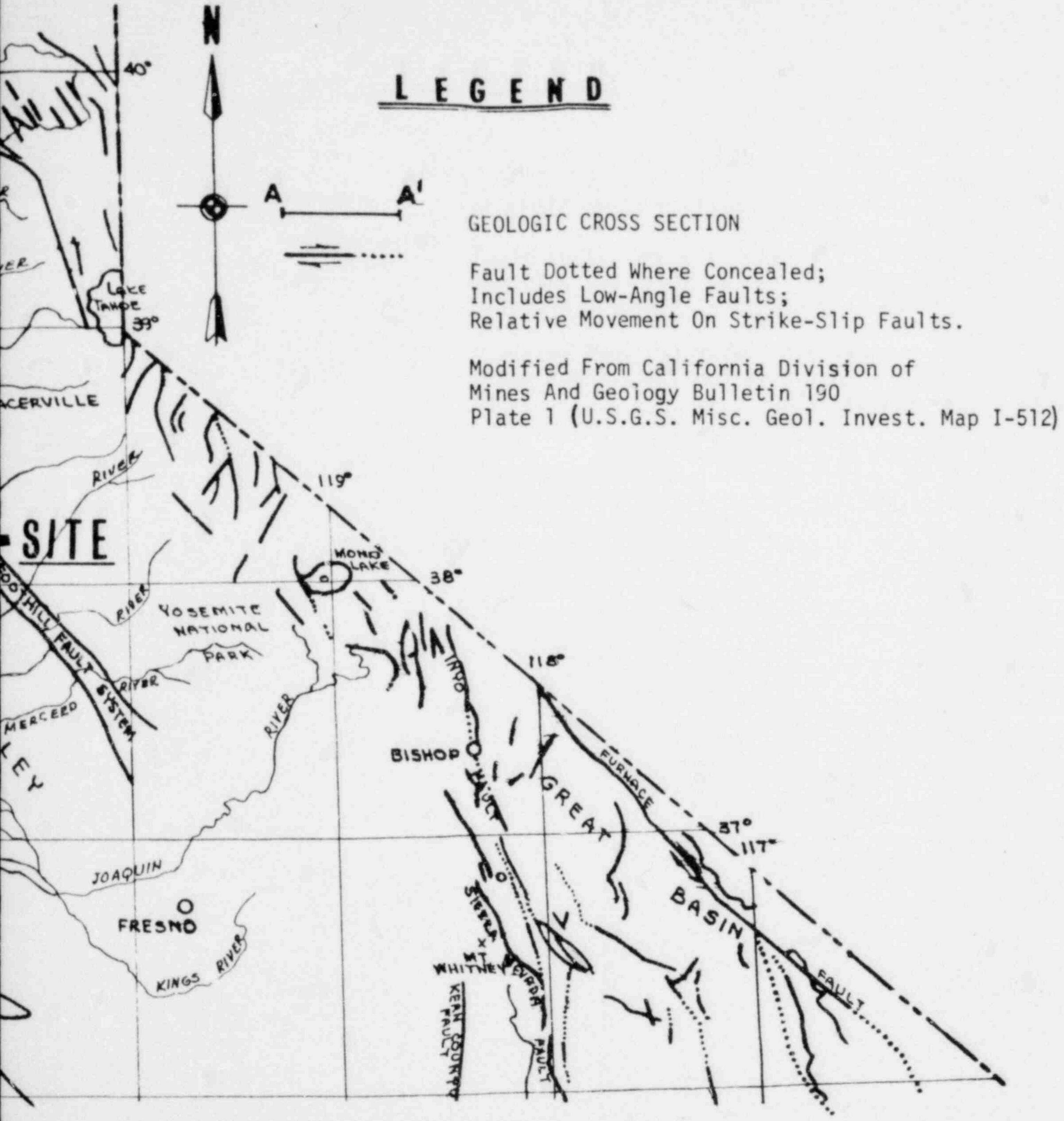
15. Curtis, G. H., "Modes of Origin of Pyroelastic Debris in the Mehrten Formation of the Sierra Nevadas," University of California Publication in Geological Sciences Vol. 29, No. 9, pp. 453-502, (1954).



From California Division Of
Mines And Geology Bulletin 190

FIGURE 2C-1
CALIFORNIA GEOMORPHIC PROVINCES


CALIFORNIA
EEL RIVER
SACRAMENTO
GREAT
FEATHER
RIVER
YUBA
NEVADA CITY
RIVER
UKIAH
RUSSIAN
CLEAR LAKE
SAN
ANDREAS
POINT REYES
SAN FRANCISCO
SACRAMENTO
RIVER
CENTRAL
AMERICAN
A
A'
HAYWARD
FAULT
SAN FRANCISCO BAY
CALAVERAS
FAULT
FAULT
COAST
RANGES
STANISLAUS
TUOLUMNE
SAN
VAL
37°
36°
MONTEREY BAY
MONTEREY
SALINAS
RIVER
SCALE 1:2500000
0
50
100 MILES



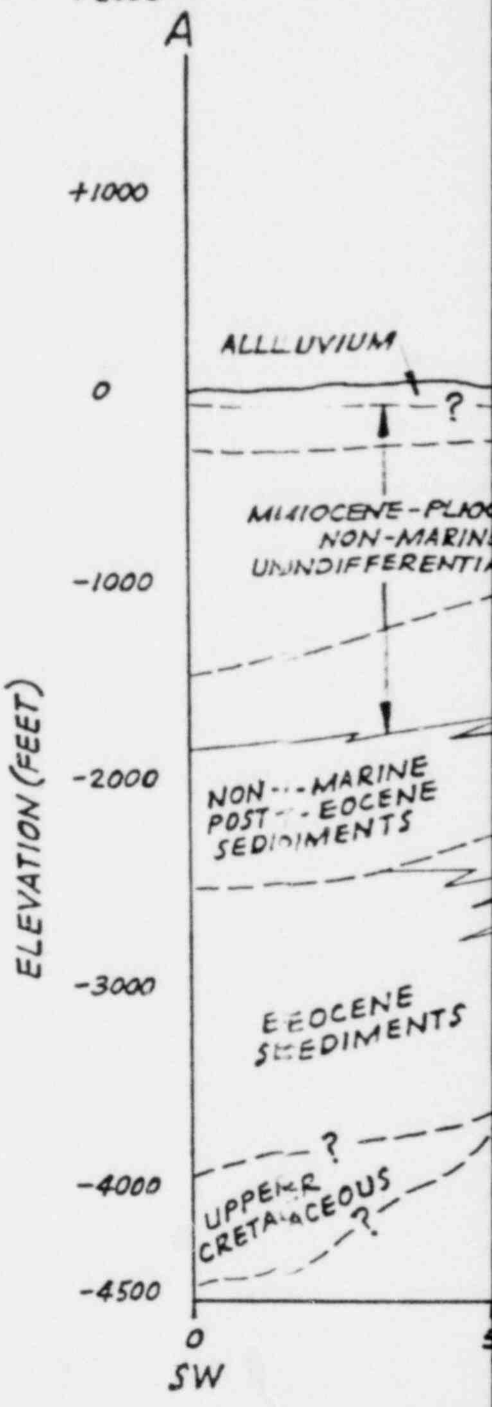
LEGEND

GEOLOGIC CROSS SECTION

Fault Dotted Where Concealed;
Includes Low-Angle Faults;
Relative Movement On Strike-Slip Faults.

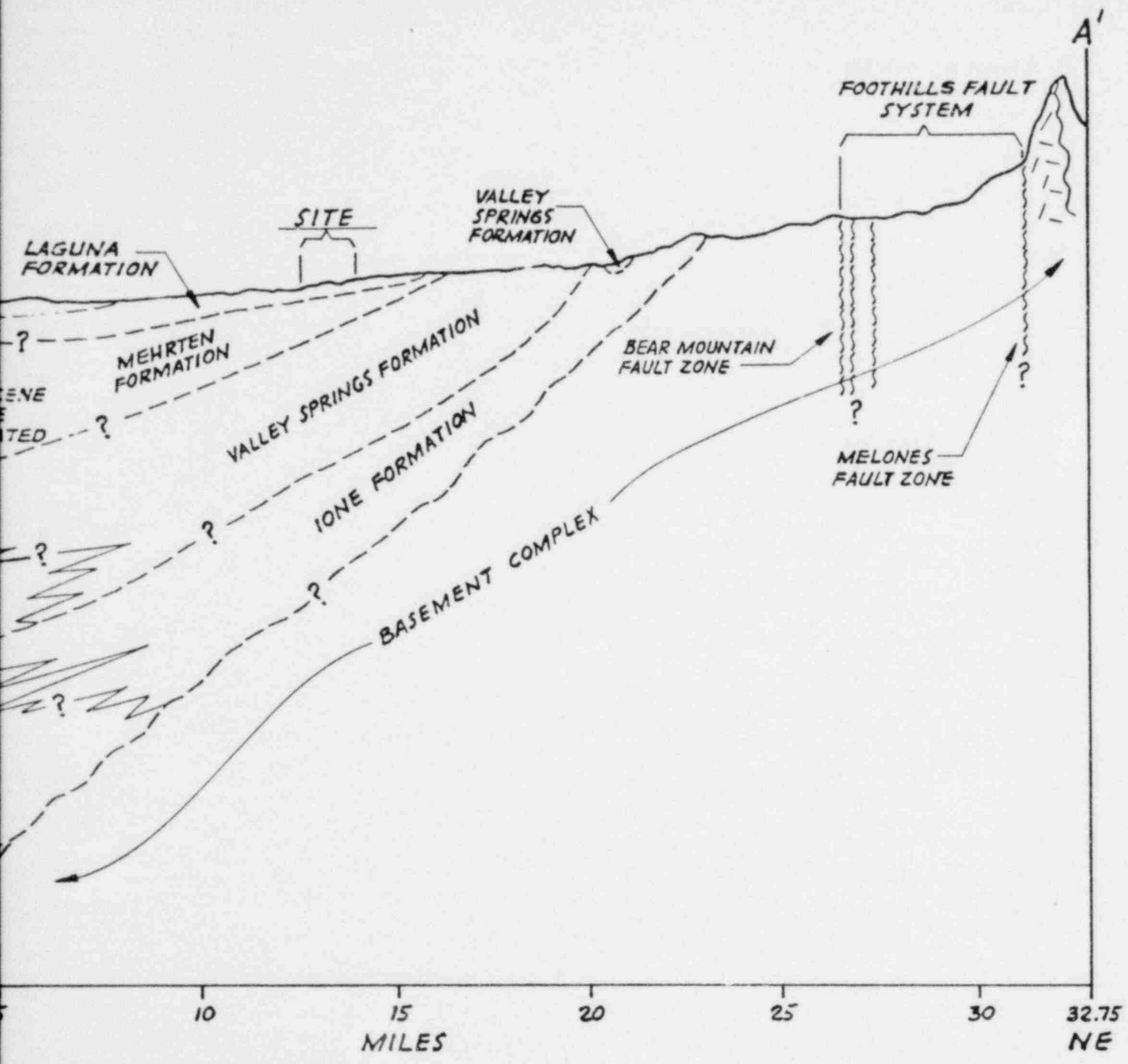
Modified From California Division of Mines And Geology Bulletin 190 Plate 1 (U.S.G.S. Misc. Geol. Invest. Map I-512)

FIGURE 2C-2
MAJOR FAULTS OF CENTRAL CALIFORNIA



NOT

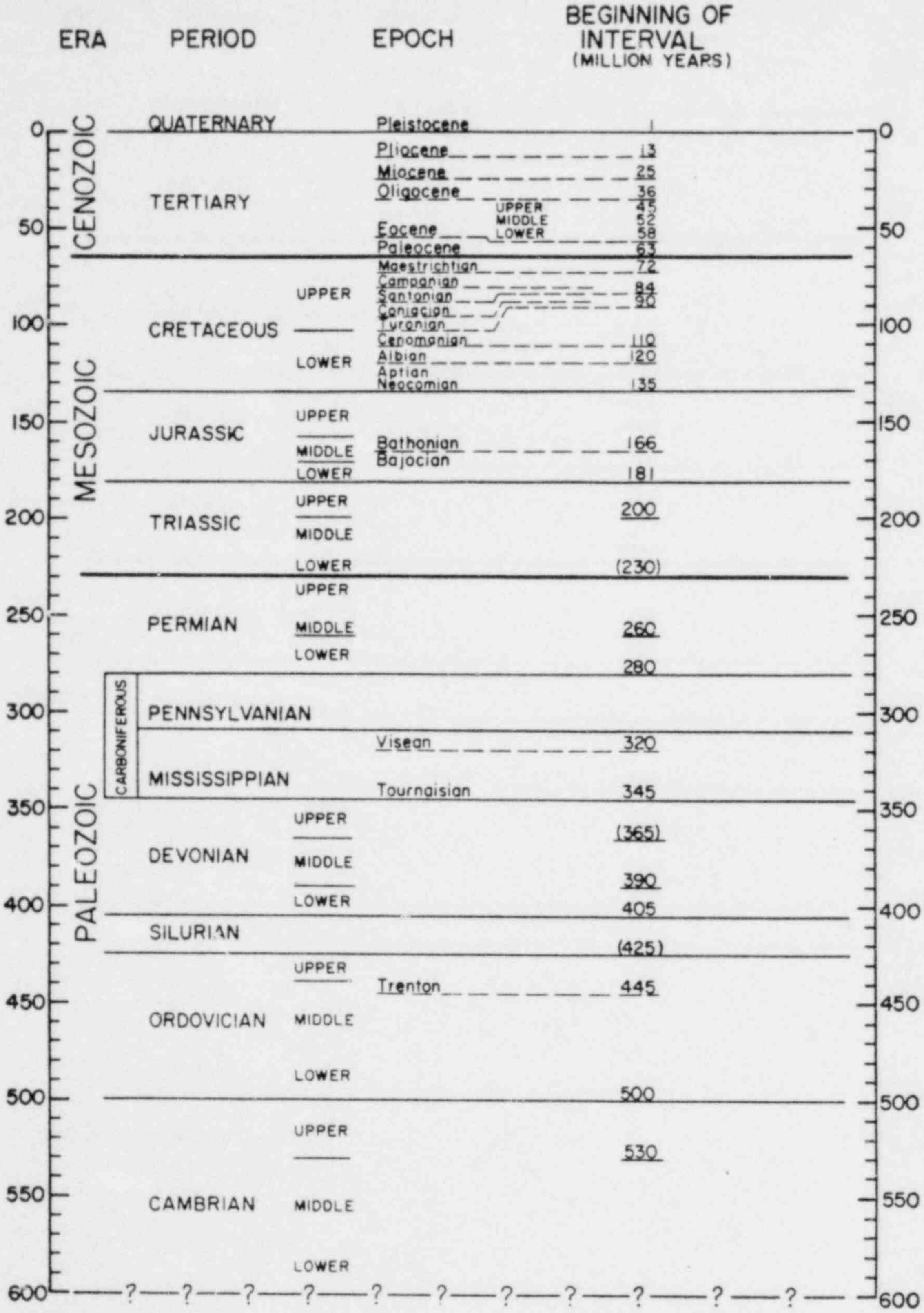
1. DER
SEC
OM
2. CON
3. EXA



ES:

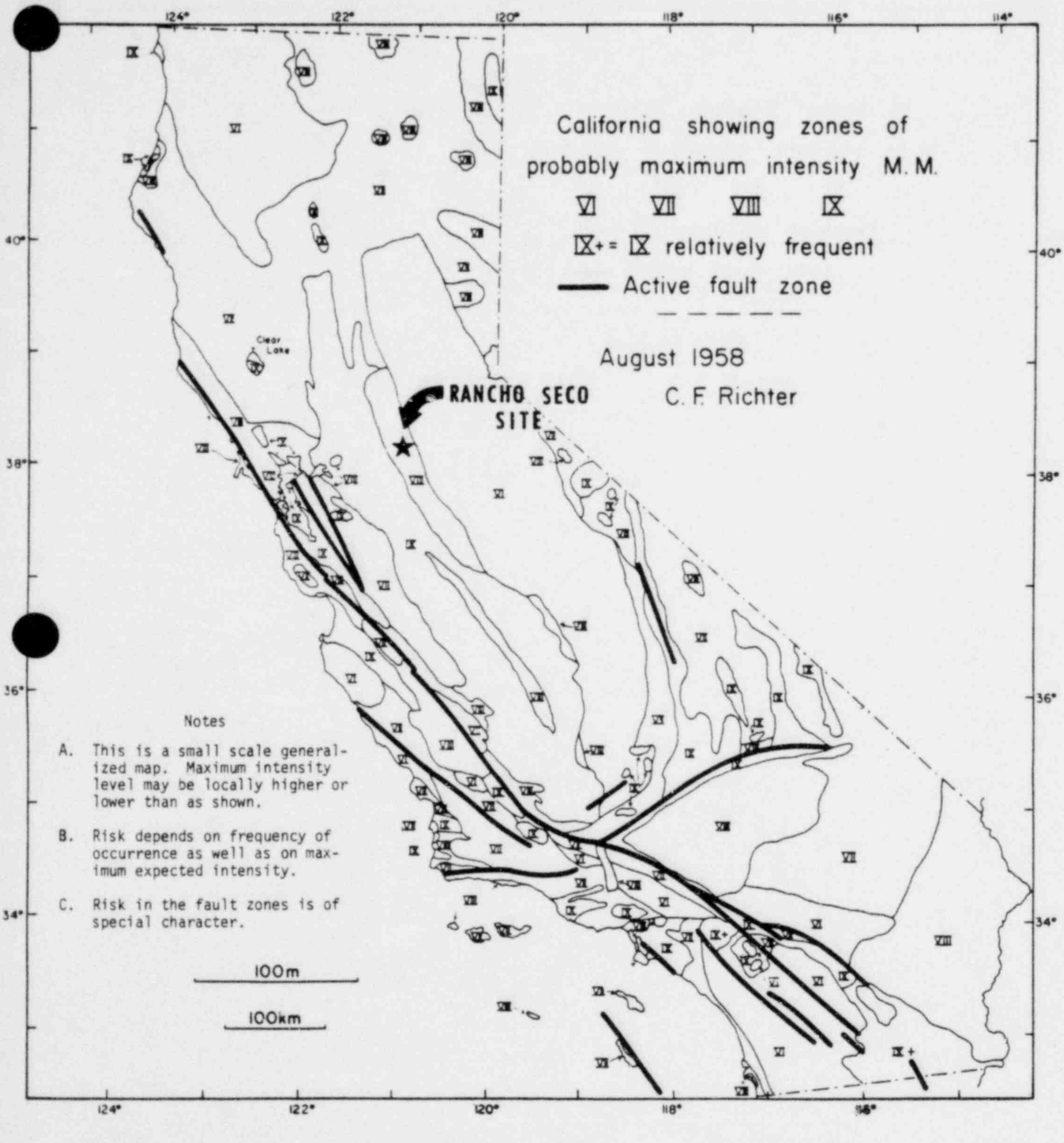
IVED FROM AAPG CENOZOIC CORRELATION
TIONS 1(1951) & 15(1967) & USGS MAP
-215 - BASEMENT CONTOURS.
TACT LINES ARE APPROXIMATE. ——?——
GGERATED SCALE - V = 1 : H = 26(±).

FIGURE 2C-3
GENERALIZED GEOLOGIC CROSS SECTION A-A'



After Kulp, J. L., Science, Vol. 133, No. 3459, April 14, 1961

FIGURE 2C-4
GEOLOGIC TIME SCALE



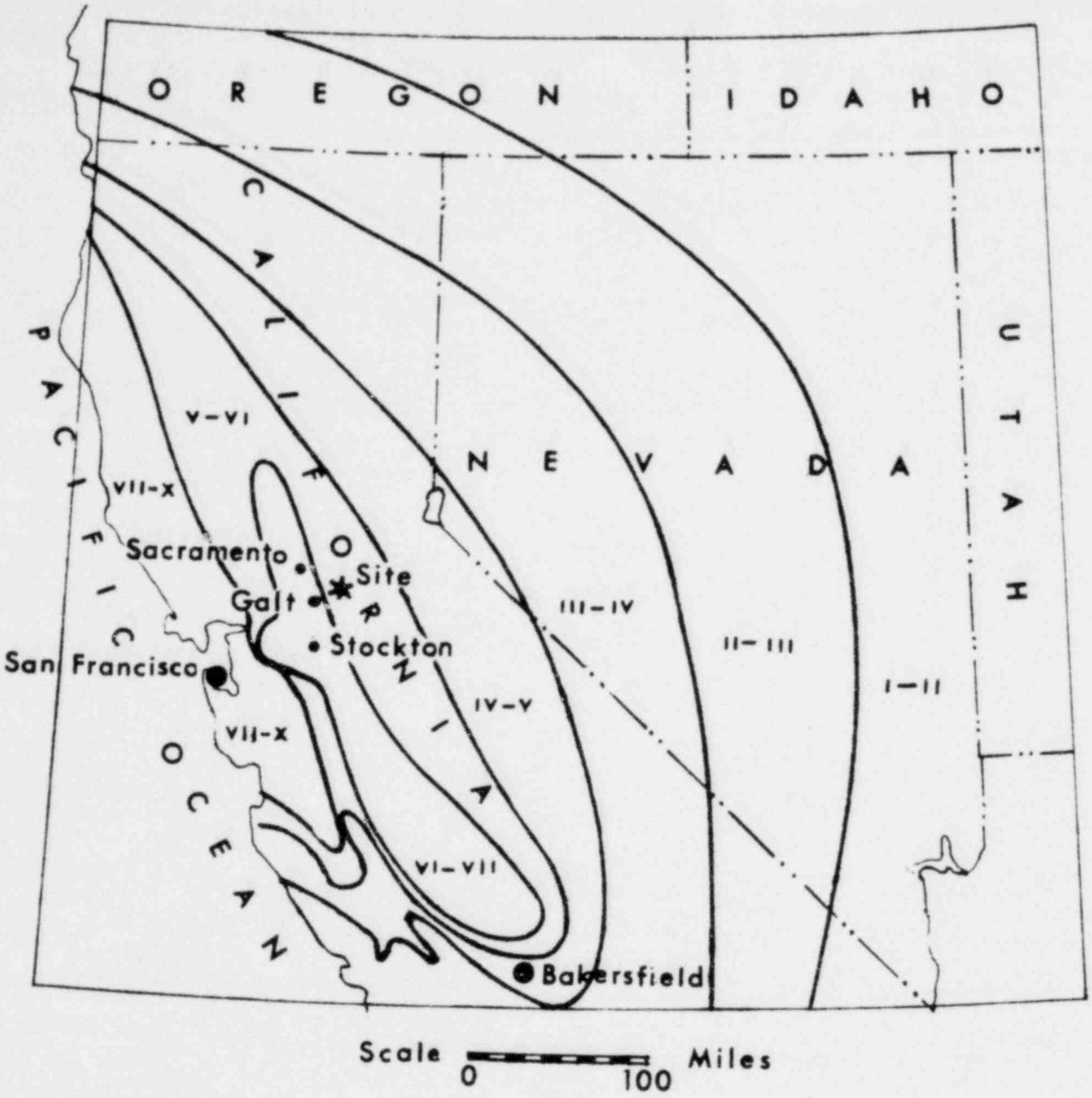
Notes

A. This is a small scale generalized map. Maximum intensity level may be locally higher or lower than as shown.

B. Risk depends on frequency of occurrence as well as on maximum expected intensity.

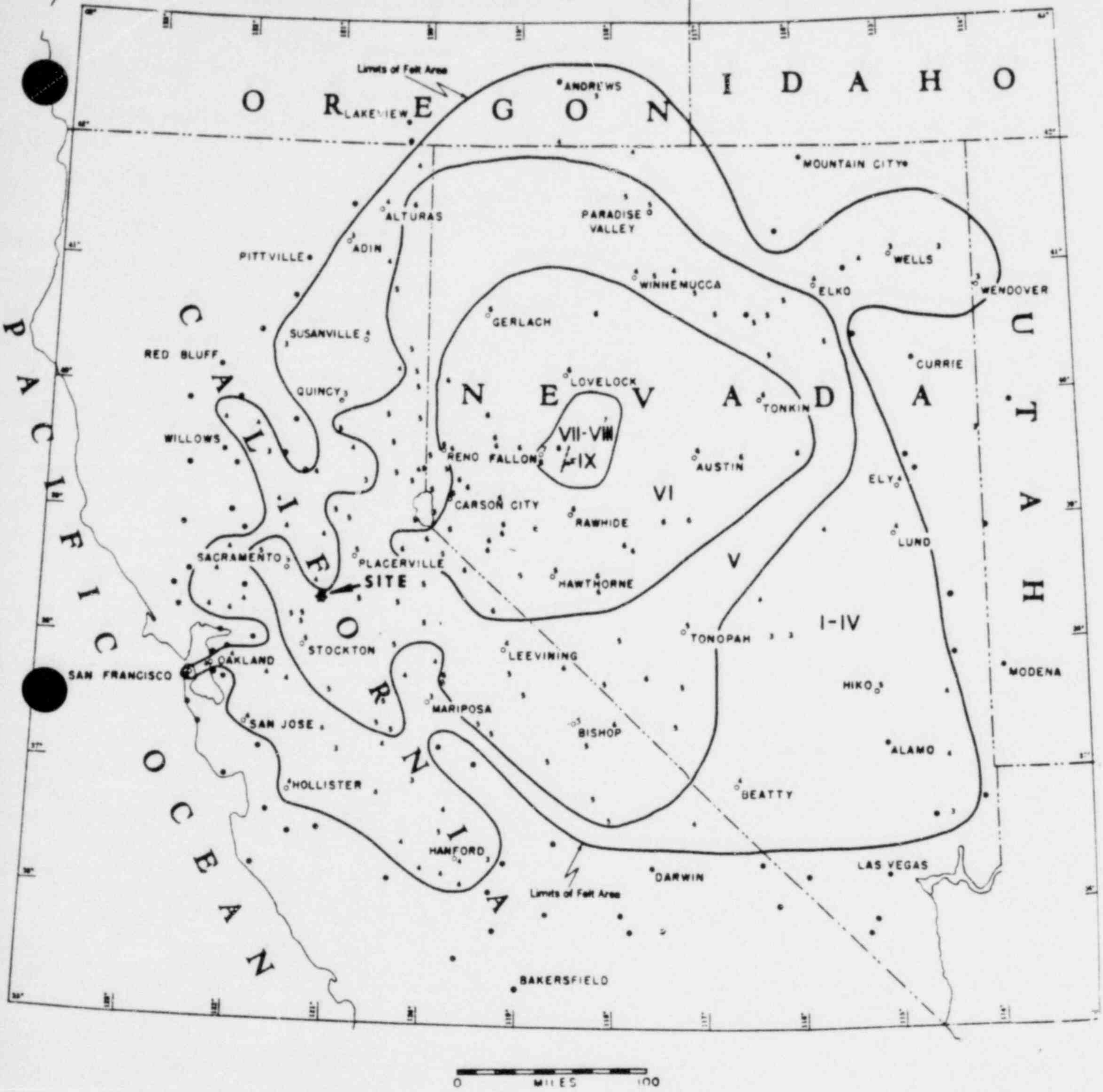
C. Risk in the fault zones is of special character.

FIGURE 2C-5
SEISMIC REGIONALIZATION



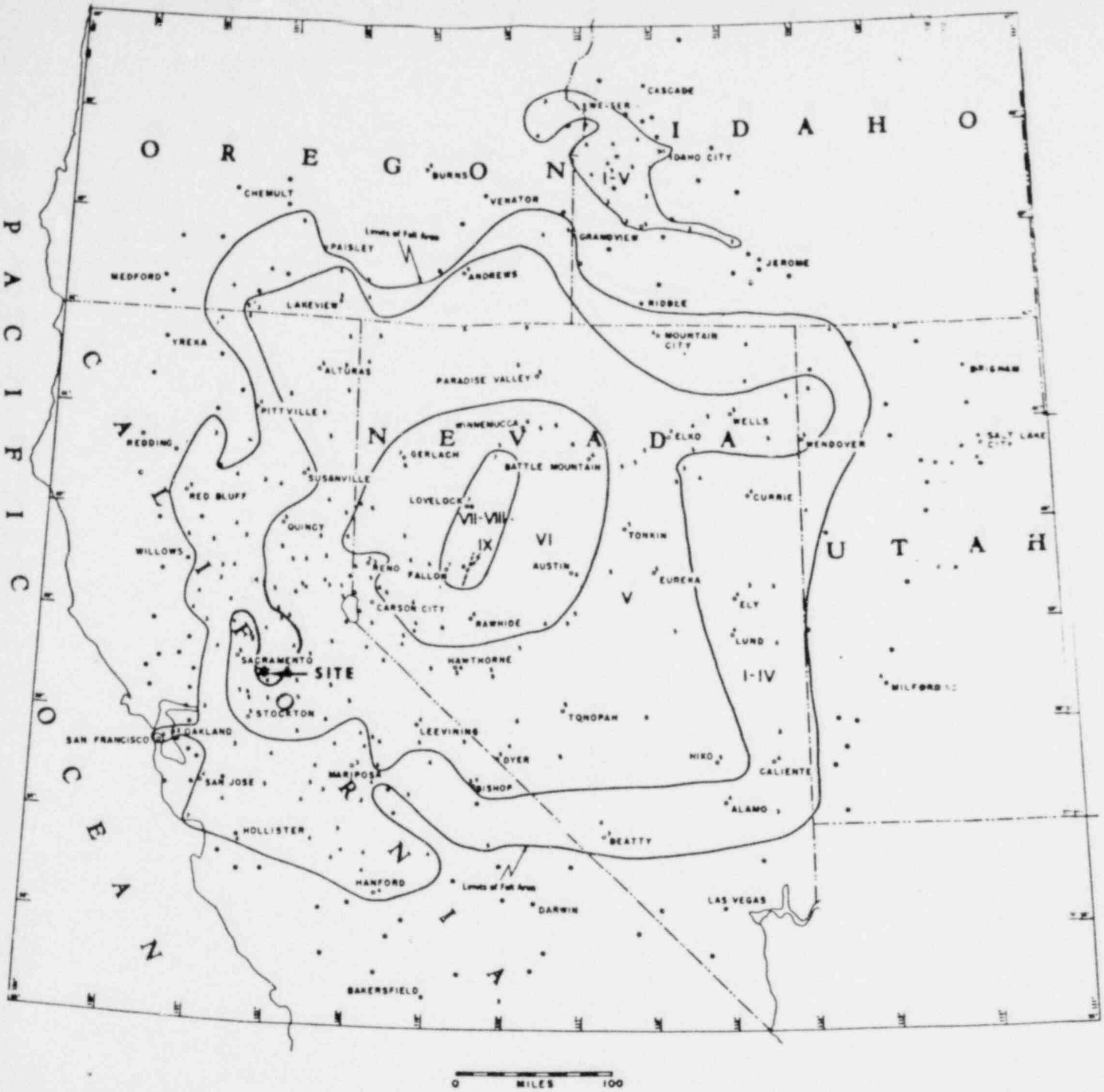
Isoseismals on Rossi-Forel Scale (Published by Modified Sketch after Map from the Report of the State Earthquake Investigation Commission, California Earthquake of April 18, 1906, Carnegie Institute of Washington, 1908)

FIGURE 2C-6
ISOSEISMAL MAP - SAN FRANCISCO EARTHQUAKE,
APRIL 18, 1906 (MAGNITUDE 8.3)



Isoseismals on Modified Mercali Scale (From Bulletin of the Seismological Society of America, Vol. 5, No. 1, 1956)

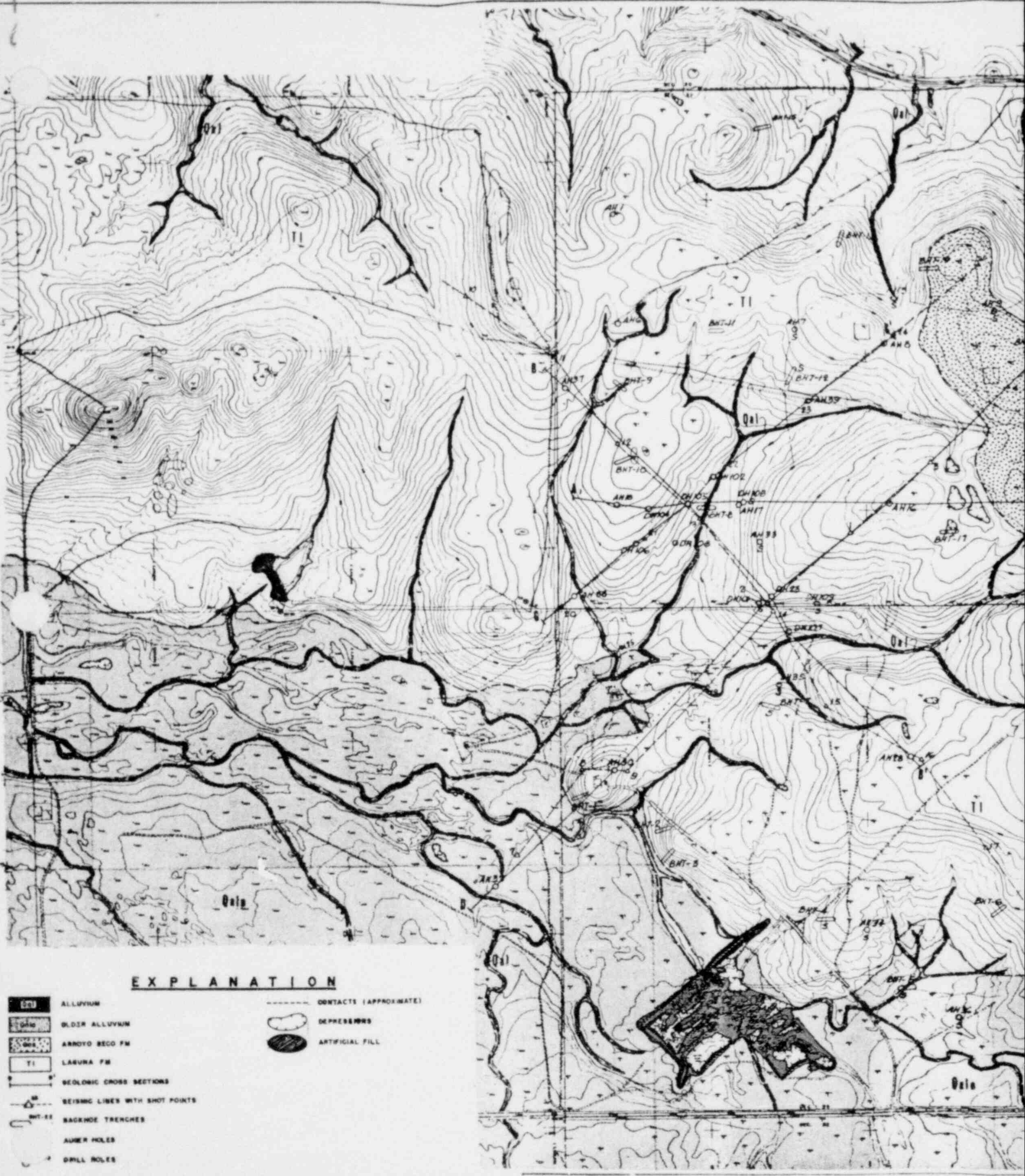
FIGURE 2C-7
ISOSEISMAL MAP - FALLON,
NEVADA EARTHQUAKE, JULY 6, 1954
(MAGNITUDE 6.8)



Isoseismals on Modified Mercali Scale (From Bulletin of the Seismological Society of America, Vol. 5, No. 1, 1956). Zone boundry between I-IV and V modified in the Site vicinity to include a pocket of IV intensity readings within the I-IV zone.

FIGURE 2C-8
ISOSEISMAL MAP - FALLON,
NEVADA EARTHQUAKE, AUGUST 23, 1954
(MAGNITUDE 6.8)

BECHTEL


Qal
Tl
Qal
Qal
Qalo
Qalo
Qal
Tl
Tl
B
B'
A
C
D
AH-1
BHT-9
BHT-10
BHT-11
BHT-12
BHT-17
BHT-3
BHT-6
AH37
AH33
DH102
DH105
DH108
DH104
DH106
AH17
AH66
AH30
EXPLANATION
Qal
ALLUVIUM
Qalo
OLDER ALLUVIUM
Qas
ARROYO SECO FM
Tl
LAGUNA FM
GEOLOGIC CROSS SECTIONS
SEISMIC LINES WITH SHOT POINTS
BHT-22
BACKHOE TRENCHES
AUGER HOLES
DRILL HOLES
CONTACTS (APPROXIMATE)
DEPRESSIONS
ARTIFICIAL FILL

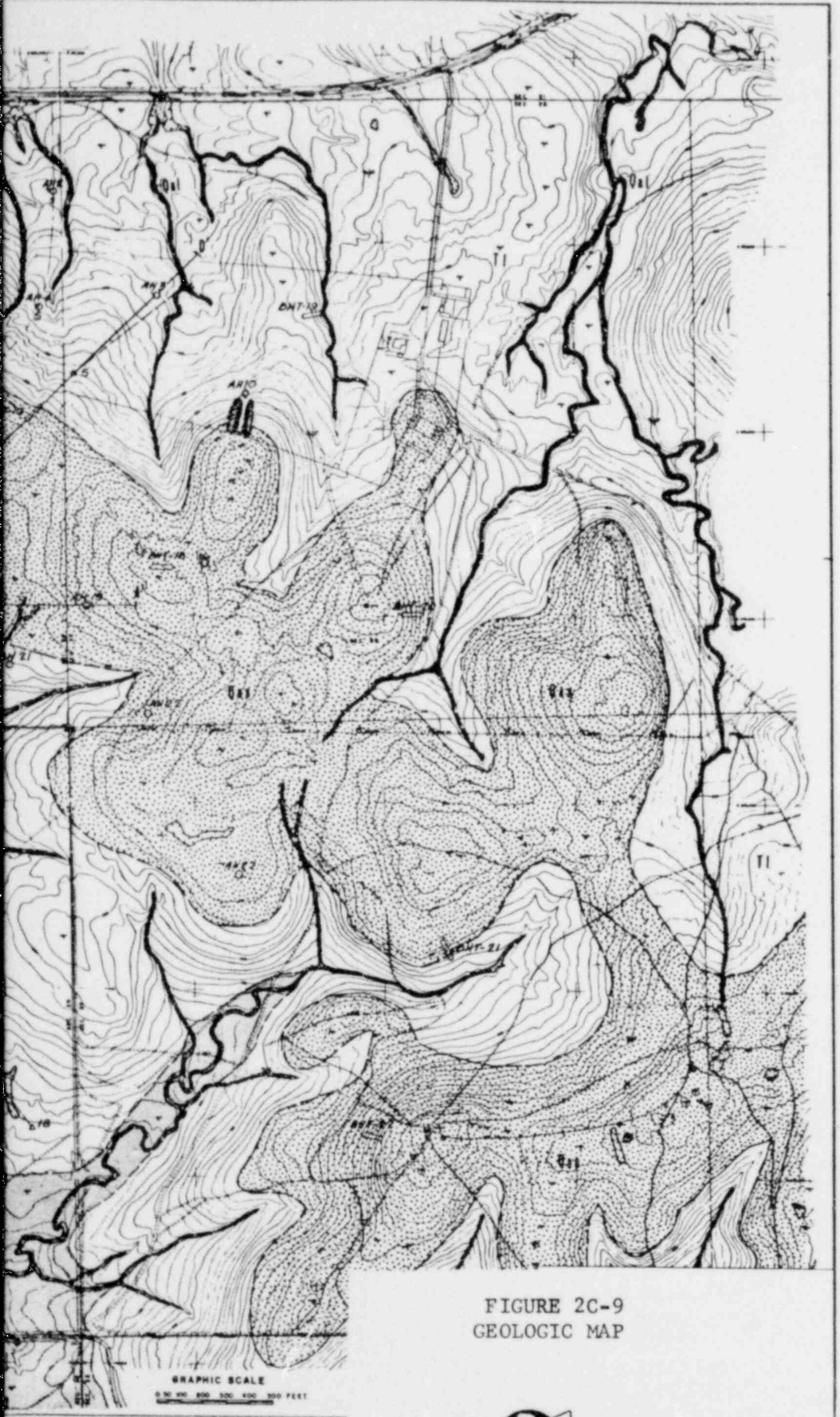


FIGURE 2C-9
GEOLOGIC MAP

DESCRIPTION

SILTY, SANDY GRAVEL (GM), red-brown to brown. Sand is very fine to fine-grained.

SILTSTONE (ML-SM), red-brown. Scattered sand and gravel. Clayey below 28'.

SILTY SANDSTONE (SM-SP), red-brown. Abundant pea gravel.

SILTSTONE (ML), red-brown. Scattered sand grains.

SANDSTONE (SM-SP), red-brown, very fine to medium-grained, silty, firm and friable.

CLAYEY SILTSTONE (ML), red-brown. Scattered fine to coarse sand grains. Soft-firm.

SILTSTONE (ML), red-brown to locally gray. Scattered sand and gravel. Firm and massive. Clayey at 75.3'.

CLAYEY, SILTY, SANDY GRAVEL (GM), gray to brown, sub-angular to round.

SILTY SANDSTONE TO SANDY SILTSTONE (SM-ML), red-brown to brown, very fine to medium grained, firm.

SANDSTONE (SP), gray, very fine-grained, poorly graded, clean and massive. Scattered vugs. Clayey siltstone at 109.8'-110.6'.

SILTSTONE (ML-SM), brown, unconsolidated to firm, massive. Scattered coarse sand and gravel. Grades to tan, fine grained, light weight sand.

SAND AND GRAVEL (SP-GP), tan to gray. Sand is fine to very coarse.

SANDSTONE (SP), tan to gray, very fine to fine grained and poorly graded.

SILTSTONE (ML), brown, massive, firm. Contains vugs.

SILTSTONE (ML), brown to red-brown, unconsolidated to firm. Locally grades to sandstone. Locally clayey.

SANDSTONE (SP), gray to blackish-brown, very fine to fine-grained, poorly graded. Grades to siltstone at 163.1'-164.0'. Contains some gravel near base.

SILTSTONE (ML), red-brown, firm to locally friable.

CLAYSTONE (CL), dark red-brown, silty, unconsolidated to slightly firm.

SILTSTONE (ML), red-brown to gray, poorly to moderately indurated, massive and clayey.

SANDSTONE WITH INTERBEDDED SILTSTONE (SP-ML), dark brown to black, friable to moderately indurated.

SANDY SILTSTONE (ML-SM), light brown to gray to black. Slightly clayey.

SANDY CONGLOMERATE (GP), gray to black. Abundant coarse sand.

SANDSTONE (SP), gray, very fine to fine-grained, massive and hard. Locally silty.

SILTSTONE (ML-SM), light gray, massive and firm. Locally sandy.

SANDSTONE (SP), light gray, very fine to fine-grained and poorly graded. Moderately hard.

CONGLOMERATE (GP)

CLAYSTONE ? (CL)

SILTSTONE ? (ML)

CLAYSTONE (CL), light brown to light gray, firm. Highly fractured.

SILTSTONE (ML), light green, firm to moderately hard.

CLAYSTONE (CH), blue-green, highly plastic and fatty. High dry strength.

SILTSTONE (ML), blue-green, firm to hard. Locally sandy below 420'.

CLAYSTONE ? (CL-CH)

CLAYSTONE AND SILTSTONE (CL-ML)

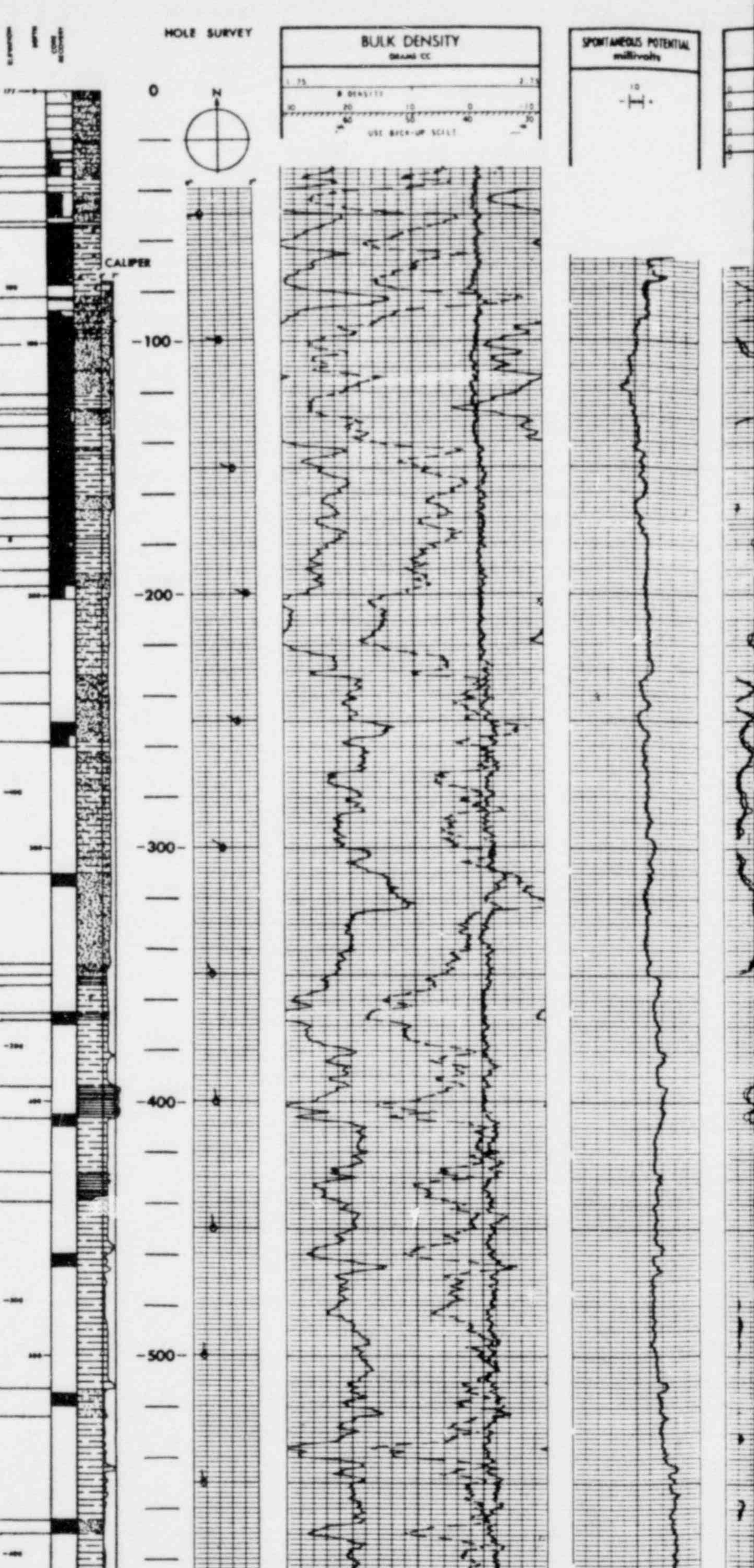
SANDY SILTSTONE (ML), white to light gray, clayey. Scattered pebbles.

SILTSTONE AND CLAYSTONE (ML-CL). Locally sandy.

SANDSTONE (SP), light olive green, very fine-grained and poorly graded. Very firm to moderately hard and massive.

SILTSTONE AND CLAYSTONE (ML-CL)

CLAYSTONE (CL), olive green, firm. Scattered sand.



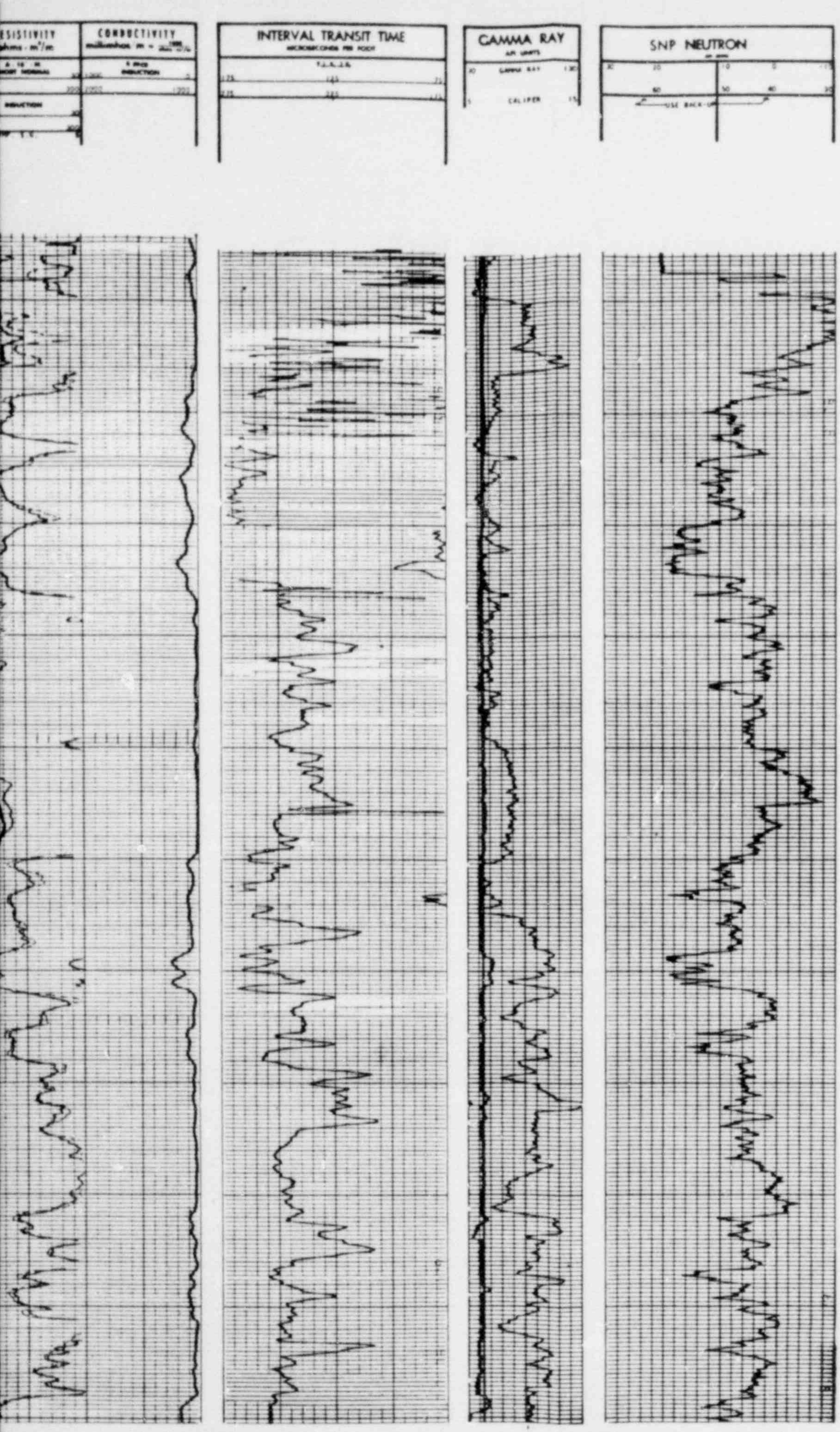
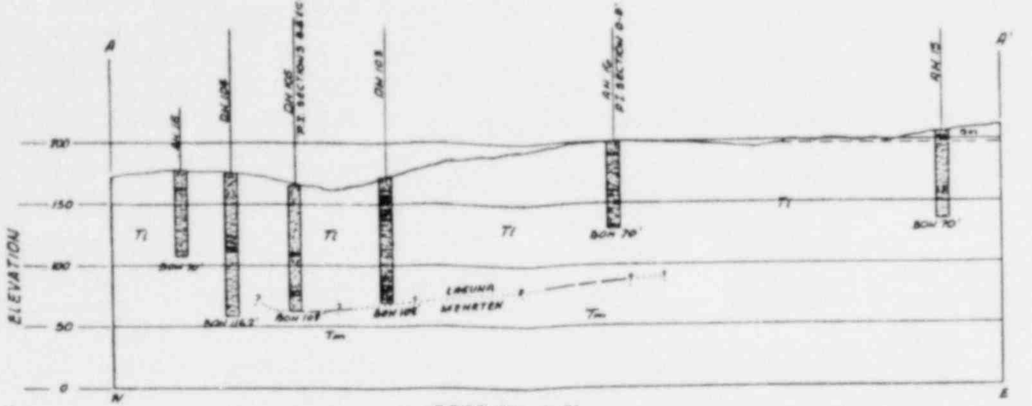
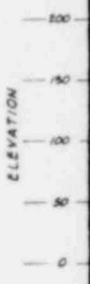


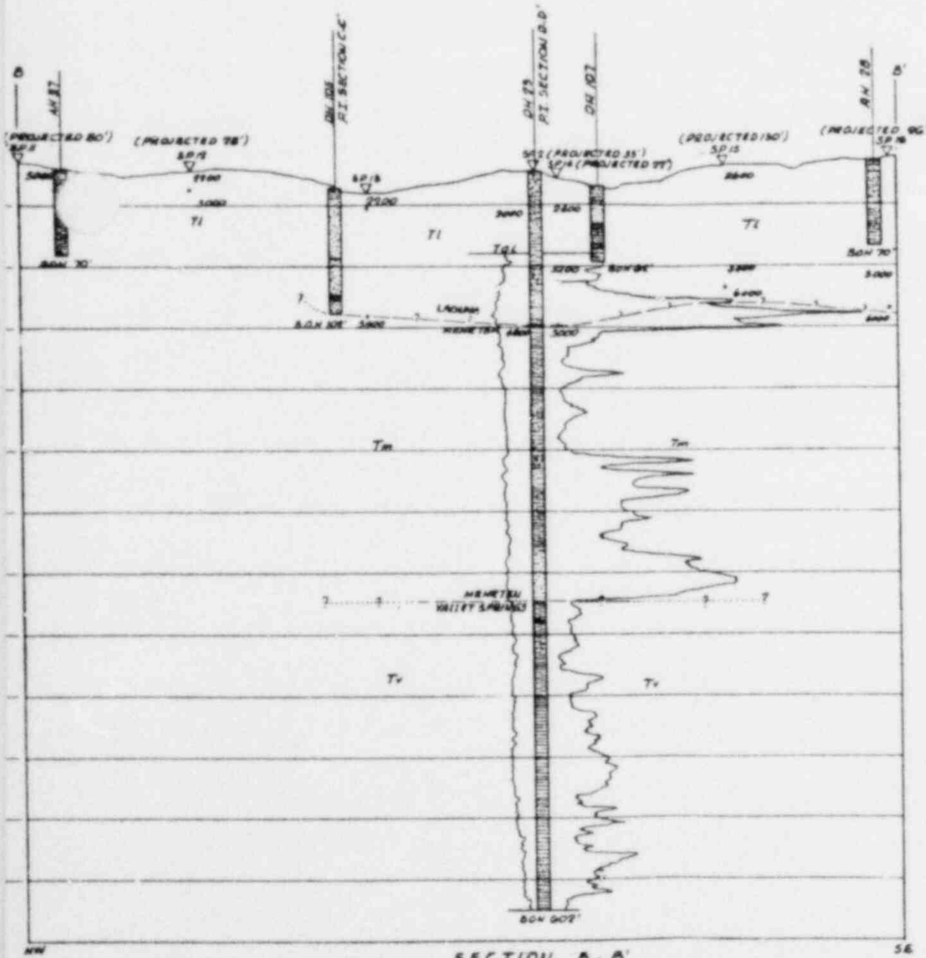
FIGURE 2C-10
GEOLOGIC LOG OF DH-23

BECHTEL

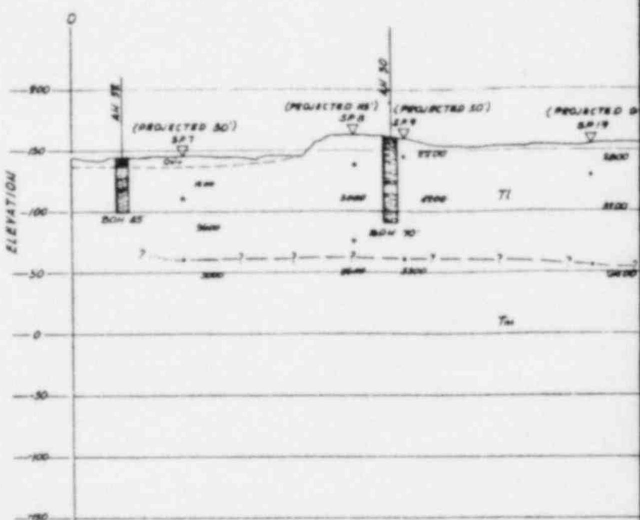


SECTION A-A'





SECTION B-B'



215

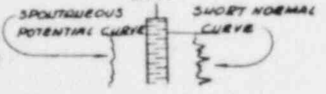
EXPLANATION

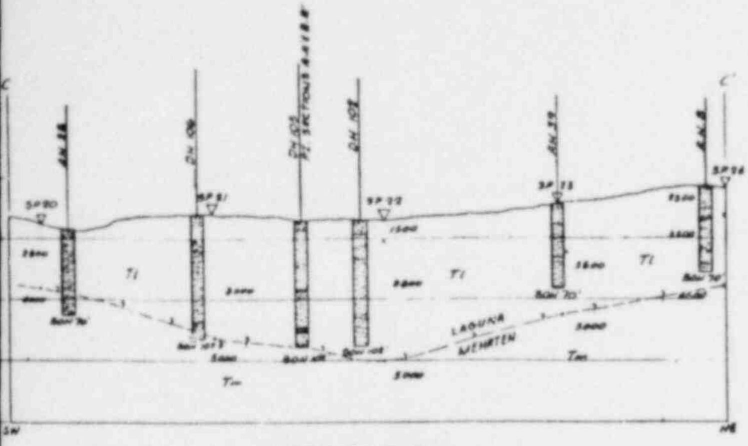
NITS
LAY, CLAYSTONE
ILT, SILT
AND, SA
GRAVEL, C MERATE
ERROTO SECO FORMATION
AGUNA FORMATION
EHRTEN FORMATION
ALLEY SPRINGS FORMATION
? FORMATION CONTACT
CONTACTS ARE INFERRED FROM VELOCITY DATA EXCEPT AT DH 23

SYMBOLS & ABBREVIATIONS

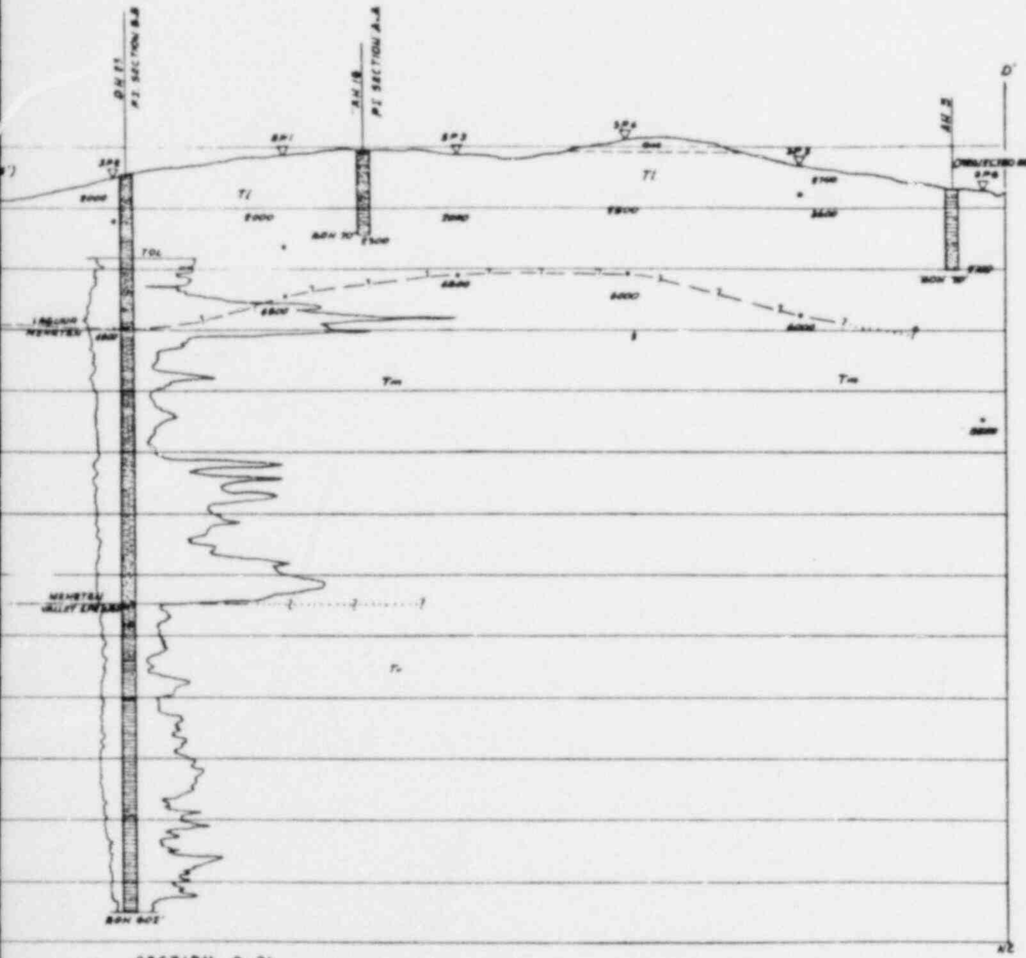
AH 39	AUGER HOLES
DH 104	DRILL HOLES
▽ 25	SEISMIC SHOT POINTS
• 3000 6000	POINT OF VELOCITY CHANGE
TOL	TOP OF LOG
BOH	BOTTOM OF HOLE
P.I.	POINT OF INTERSECTION

KEY TO ELECTRIC LOG





SECTION C-C'



SECTION D-D'

FIGURE 2C-11
GEOLOGIC CROSS SECTIONS
A-A', B-B', C-C', AND D-D'

BECHTEL