UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of PACIFIC GAS AND ELECTRIC COMPANY (Diablo Canyon Nuclear Power Plant, Units 1 and 2)	)	Docket Nos. 50-275 50-323

AFFIDAVIT OF DOUGLAS H. HAMILTON

STATE OF CALIFORNIA COUNTY OF SAN FRANCISCO	)	ss.

I, Douglas H. Hamilton, being duly sworn, depose and say:

I am currently President and principal geologist of Earth Sciences Associates Inc. of Palo Alto, California. My credentials have previously been submitted to the Atomic Safety and Licensing Appeal Board in these proceedings.

A. <u>Regarding the location and subsurface geometry of the Hosgri Fault</u>

Brune states that "although the exact dip of the Hosgri fault under Diablo Canyon has not been determined, based on the Crouch *et al*. paper, it is possible that the fault could be less than 3 km beneath the Diablo Canyon site. Furthermore, since the fault presumably could extend, dipping, many kilometers to the east, a rupture could initiate at depth tens of kilometers to the east of the site and propagate up-dip, focusing energy toward the site and causing much higher accelerations than previously anticipated." (Brune aff. at 7)

In fact, based on all available evidence, including the referenced Crouch *et al*. paper and another by Eaton, discussed subsequently herein, it is my opinion that the Hosgri fault is not any closer than approximately 8 to 10 kilometers beneath the site.

The location of surface traces associated with the Hosgri fault zone were shown on maps presented by Wagner, (1974) and in Appendix 2.5 D to the DCPP FSAR (1974), prepared by the undersigned. The subsurface geometry of the Hosgri zone was illustrated in Figures 36 and 37 of the 1978 ASLB prefiled direct testimony by Hamilton and Jahns. Figure 36, derived from a migrated proprietary CDP seismic reflection line, shows a series of steeply dipping faults extending to the sea floor and representing the Hosgri fault zone as it is shown on surface maps, and a single break at a depth of about 1 km that dips about 50° east. If projected down dip, this break would extend beneath the steeply dipping near surface breaks and on beneath the plant site at a depth of about 10 kilometers. This is illustrated by the dashed line added to Figure 36 of Hamilton and Jahns, 1978, attached.

Since the recent publication of the paper by Crouch et al. (1984), I have again reviewed proprietary CDP seismic reflection data that were reviewed for the 1978 ASLB hearing (represented in part by Figure 37 of the 1978 ASLB direct testimony of Hamilton and Jahns), in order to reevaluate the location of the Hosgri fault zone as previously represented in the 1974 FSAR, the 1978 ASLB testimony, and Wagner (1974) in light of the Crouch et al. map (Figure 10 from Crouch) and line drawings of CDP seismic reflection lines (Figures 5, 6, and 8 from Crouch). My conclusions from that review are as follows:

1. The Hosgri fault zone, if interpreted according to the form indicated in the illustrations in Crouch et al., lies generally beneath or somewhat seaward (west) of the zone of faults shown on maps such as Figure 35 of the 1978 ASLB testimony by Hamilton and Jahns and in Wagner (1974). There is no basis from the Crouch et al. paper or from my recent reevaluation for suspecting that the trace of the

Hosgri fault is closer to the Diablo Canyon site than shown on maps previously available.

2. The dip of the Hosgri fault as it is illustrated in the area near Pt. Sal by Crouch et al. (1984) steepens northward from 17 to 35 degrees 1/ among the examples they show (their figures 5, 6, and 8). Focal mechanism solutions for earthquakes located near Pt. Sal, 22 km south of Diablo Canyon, and north of San Simeon, more than 100 km north of Diablo, show eastward dips of 35° and 55°, respectively. The interpretation previously developed and used as Figure 36 in the 1978 ASLB testimony showed the reverse fault beneath the Hosgri surface traces to dip 50° eastward. This latter value, 50° east, is based on data previously filed, and is in general agreement with the dips indicated by Crouch et al. (1984) and by Eaton (1984).

1/ The three line drawings in Crouch et al. show dips on the farthest down-dip indication of the Hosgri of 17, 20, and 26 degrees northeast, respectively, going from south to north. The latter two drawings, however, are from lines oriented at about 45 degrees to the strike of the Hosgri zone and so record apparent rather than true dips. The corresponding true dips would be 26 and 35 degrees.

In addition to the data in the recent article by Crouch et al., the results of studies of the focal mechanisms of 6 earthquakes that originated at points some tens of km north and south of Diablo Canyon have recently been presented in Eaton (1984).

As noted by Brune (p. 17), Eaton states that "the earthquakes reported here show a steady change in character in accordance with the location of the earthquakes.... For the choices of fault plane indicated above, the corresponding progression in style of faulting is from left lateral reverse oblique, through simple reverse, to right lateral strike slip." This observation accords with previous testimony by Hamilton and Jahns during the 1978 ASLB hearing (prefiled direct testimony, 116, 124) and by Hamilton during the 1980 ALAB hearing. "Fault type--Hosgri fault: Right oblique, with fold and reverse fault transition to San Simeon fault to north" (prefiled direct testimony of Hamilton, V-13, Table B).

This accord is also evident to Brune (p. 17), who states that "the pattern of fault plane solutions reported in the Eaton paper outlines a coherent tectonic pattern in the region of the Hosgri fault, and indicates that a right lateral reverse fault with a significant amount of thrust motion can be expected in the region of the Diablo Canyon site." (Brune aff. at 17)

Two further aspects of Eaton (1984) are important in the context of points offered by Dr. Brune:

(1) The San Simeon earthquake of 29 August, 1983, had a hypocentral depth of 6.6 km and a focal mechanism indicating a strike of N39W and a dip 55° NE. The plane of rupture defined by this mechanism projects upward nearly directly to the offshore trace of the San Simeon fault. This demonstrates that the San Simeon fault, the next major segment north of the Hosgri fault within the "San Gregorio-Hosgri fault system" does not flatten downward but rather extends directly down dip to seismogenic depth. Thus, there is no basis in the seismologic evidence of Eaton (1984) to infer down-dip flattening of the Hosgri fault in its central reach opposite Diablo Canyon.

(2) The Pt. Sal earthquake of 29 May, 1980, and the June 20, 1984, earthquake at nearly the same location, cited by Brune (p. 16) each occurred at hypocentral depth of about 9 km (9.2 and 9.4 km, respectively). The line drawing cross section presented as Figure 5 in Crouch et al. (1984), however, clearly shows that at the latitude of Pt. Sal the dip of the Hosgri fault flattens below about 1 km depth to about 17° E and the fault

plane lies at a depth of about 1.5 km in the immediate vicinity of the epicenters of the two earthquakes. The two Pt. Sal earthquakes described by Eaton, as cited in Brune, therefore occurred some 7 to 8 km beneath the Hosgri fault, not on it. Thus, none of the earthquakes described by Eaton occurred on the Hosgri fault. 2/

B. Regarding the rate of tectonic deformation in the region of the Hosgri fault.

Brune advances the view (p. 17) that the 6 earthquakes reported on by Eaton (1984) constitute "direct evidence of recent high seismicity." This of course carries with it an implication of a contemporary high rate of tectonic deformation in the region. He then quotes another recent paper, this one entitled "Vector Constraints on Quaternary Deformation of the Western United States East and West of the San Andreas fault" by J. Bernard Minster and Thomas H. Jordan (1984), as follows: "we show that deformation west of the San Andreas must involve 4 - 13 mm/yr of crustal shortening orthogonal to this fault and

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2/ The fault upon which these earthquakes occurred may project upward to the sea floor as the offshore Lompoc fault, shown on Figure 43 of the 1978 ASLB direct testimony of Hamilton and Jahns. The near surface part of this fault is associated with an active fold in the sea floor.

6-25 mm/year of right lateral motion parallel to it... If all strike slip motion is taken up on the San Gregorio-Hosgri fault system, then the rate of strike slip projected into the N20°W trend of the San Gregorio fault trace must be no less than 8 mm/yr and no more than 27 mm/yr. Motion orthogonal to the San Gregorio is not resolvably different from zero but is constrained by geological and seismic data to be compressive; our analysis implies it can be no larger than 7 mm/yr." This claim of high seismicity and implication of a high rate of tectonic deformation is contrary to three considerations:

1. None of the earthquakes reported on in Eaton (1984) occurred on the Hosgri fault.
2. Crouch et al. (1984) show in their line drawing seismic reflection profiles across the Hosgri fault that thrust displacement of the early Pliocene (c.3 my old) Sisquoc Formation is only about 100 m. This amounts to an average movement rate of 0.03 mm/yr.
3. The evidence previously cited by Hamilton and Jahns (1978) (direct testimony to ASLB 128-131) and Hamilton (1980) (direct testimony to ALAB V-8) that detailed study of the sea floor along fault traces within the Hosgri zone, has shown that only minor, local deformation is present along traces within the zone. This indicates that earthquakes

large enough to create either extensive surface displacements or surface warping or folding have not characterized the Hosgri fault for at least the last 10,000 to 15,000 years.

In addition to the direct evidence consisting of low contemporary seismicity and absence of extensive sea floor deformation, discussed above, the data presented in Crouch et al. (1984) has another implication, this one concerning the long-term pattern and rate of tectonic deformation associated with the Hosgri fault. This is indicated by the interpretation shown in all of the Crouch et al. (1984) line drawings of seismic reflection profiles across the Hosgri fault near Pt. Sal. The profiles all show that, at most, about 1 km. of displacement has occurred within the stratigraphic section cut by the fault, since before the time of disposition of a layer identified as "near top Miocene" (i.e. - about 7 million years ago). These profiles also appear to show that the stratigraphic sections (i.e. the body of layered rocks) on opposite sides of the Hosgri fault are similar, further indicating that little displacement, either thrust or strike slip, has occurred along the Hosgri during at least the last 7 million years. This evidence indicates that the rate of tectonism of the Hosgri fault is even lower than was indicated in conclusions reached previously by Hamilton and Jahns (1978)

(ASLB direct testimony, p. 118, 126) that post Miocene offset along the Hosgri fault was no more than 20 km and probably less, and by Hamilton (1980) (ALAB direct testimony, p. V-14) that the long-term average rate of movement along the fault was in the range of 0.05-0.10 cm/year.

C. Regarding the significance of the article "Seismic Potential Revealed by Surface Folding: 1983 Coalinga California Earthquake" by <u>Ross S. Stein and Geoffrey C. P. King (1984).</u>

Brune (p. 19) cites Stein and King (1984) for the premise that "this new evidence for the existence of concealed thrust faults capable of generating earthquakes of at least M = 7.5 has an important bearing on the seismic hazard evaluation of the Diablo Canyon site. Because of the recent evidence of thrust faulting in this region given by Crouch <u>et</u> <u>al</u>. (1983), the hidden subsurface slip on these faults may be much greater than that directly manifested at the surface. There is no known reason why concealed thrust faulting of the type observed for the Coalinga earthquake could not occur near the Diablo Canyon site. Because of this, without detailed study, it is not possible to eliminate the possibility of a concealed thrust fault even closer to the Diablo Canyon than suggested by Crouch <u>et</u> <u>al</u>. The folds and minor faults indicated in the Preliminary Geologic Map Offshore from the San Luis Range, South-Central Califonria by H. C. Wagner (Plate 2, USGS Open-File Report

74-252) could be indications of concealed thrust faults with surface projections as close as 2-3 km offshore from the Diablo Canyon site, and dipping under the plant to even closer distances."

The cited article describes evidence related to and studies of, the geotectonic circumstances associated with the 1983 Coalinga earthquake, which occurred in the crust beneath an active fold. It also brings forward evidence regarding 3 other earthquakes that have been identified as occurring under similar circumstances. The article thus focuses attention on the fact that potentially seismogenic reverse or thrust faults may be represented at the surface by active folds, rather than by recognizable scarps or other direct evidence of fault rupture. This broadens the criteria for the identification of sites of past and potential future earthquakes to include active folds. But it is important in the context of Brune's comment "There is no known reason why concealed thrust faulting of the type observed for the Coalinga earthquake could not occur near the Diablo Canyon site" to note that Stein and King are referring specifically to <u>active</u> folds and that topographically conspicuous folds are present at the locations of all of the examples they cite. Furthermore, they show that rapid surface deformation of one to several meters vertical extent occurred in connection with each example. This is highly significant in that it shows that active folds are manifested by readily detectable evidence of deformation of the ground surface (including the sea floor). Conversely folds that are not "active" (or for which the rate of deformation, hence internal fault slip, is so low as to not create deformation of a surface datum), do not have surface expression other than possibly, through differential erosion.

With regard to the region of the Hosgri fault, detailed study (e.g. Diablo Canyon FSAR Appendix D, 1974, and Appendix E, 1975) has shown that folds associated with the Hosgri fault lie within the rock section that has been bevelled by erosion some 10,000-15,000 years ago, and that this datum is not itself folded. Hence such folds, including those cited by Brune as having been shown on Plate 2, USGS Open-File Report 74-252 by H. C. Wagner, are not active. In contrast the fold identified as the offshore Lompoc anticline and fault, located 13 km west of the Hosgri fault and 40 km south of Diablo Canyon, is an obvious example of an active fold. This feature has previously been identified as a likely source of the M7.3 Lompoc earthquake of 1927 (e.g. ASLB testimony by Hamilton and Jahns, p. 124

(1978) and by Smith, p. 25, (1978), and ALAB testimony by Hamilton, p. IX 1-5 (1980).

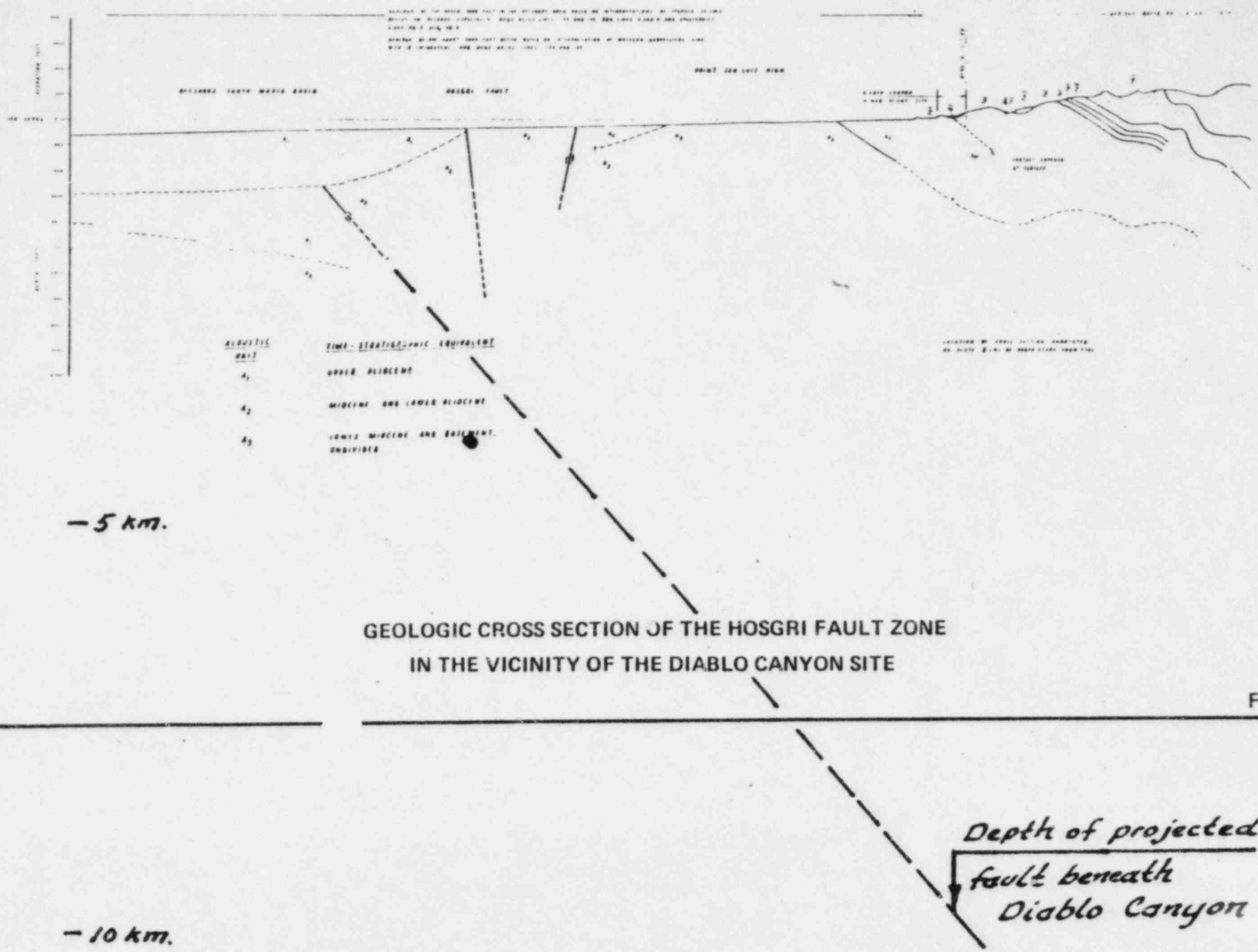
DATED: July 27, 1984

Douglas H. Hamilton

Subscribed and sworn to before me this 27th day of July, 1984

C. T. NEAL MADISON
NOTARY PUBLIC — CALIFORNIA
CITY AND COUNTY OF
SAN FRANCISCO
My Commission Expires Dec. 27, 1985

C. T. Neal-Madison
Notary Public in and for the
City and County of San Francisco,
State of California.
My commission expires
December 27, 1985



GEOLOGIC CROSS SECTION OF THE HOSGRI FAULT ZONE
IN THE VICINITY OF THE DIABLO CANYON SITE

Figure 36