TESTIMONY OF RENNER B. HOFFMAN

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CONTENTION 2

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

TESTIMONY OF RENNER B. HOFMANN

My name is Renner B. Hofmann. I am assigned to the Office of Standards Development of the United States Nuclear Regulatory Commission as a Seismologist. I have occupied this position since July of 1978. I was the Principal Seismologist reviewer for Diablo Canyon from October 1974 to July 1978 and was Leader of the Geology/Seismology Section in the Office of Nuclear Reactor Regulation from July 1976 to July 1978. My degrees include an M.S. in Seismology and a B.A. in Geology with a Mathematics minor. Attached is a copy of my *curriculum vitae*.

This testimony is in response to Intervenor's contention number 2 which read as follows:

> What ground acceleration from a 7.50 earthquake on the Hosgri fault do you contend constitutes a proper, conservative value for use in evaluating the seismic safety of the DCNGS? Please state each and every fact upon which you base this contention.

To prepare my analysis, I began by reviewing the Applicant's PSAR. I made site visits, met with the applicant, his consultants, geological survey staff, and NRC consultants. I reviewed the intervenor's contentions literature published by their consultants and other pertinent technical literature. I attended professional society meetings where topics of applicability to the Diablo Canyon application were being reported or discussed. I visited the Shell Oil Company in Houston, Texas to examine the proprietary Seismic Profiles used by Hoskins and Griffiths (1971) to identify the fault now known as the Hosgri fault. I prepared draft responses to the intervenor's contention, met with USGS representatives, legal staff and the Geoscience Branch Chief on several occasions. The Branch Chief subsequently modified and edited my response which now appears as the staff response of October 23, 1978.

In addition, my analysis revealed that The Hosgri fault is relatively long and shallow. The tectonic characteristics of the region indicates that, if a magnitute 7.5 earthquake should occur, on the Hosgri fault it would involve predominately strike slip motion. For this magnitude and a shallow strike slip mechanism, the length of fault rupture would be at least several tens of miles and possibly many tens of miles similar to the long strike slip breaks that have occurred in earthquakes on the San Andreas fault.

Generally, the stresses which lock faults are believed to be lower for strike slip faults than for reverse faults. In the case of a reverse fault, the two sides of the fault are being forced together by tectonic stresses. This increases the effective stress on the fault as regional stresses increases. Under these conditions the stress can reach extremely high levels before the frictional force is overcome and the fault slips. In the case of strike-slip faults, because the forces are generally parallel with the plane of the fault, the levels of effective stress are not as high as those involved in reverse or thrust faults (Thatcher and Hanks, 1973). Evidence of lower effective stress on faults of the San Andreas system may be seen in the determination of length of rupture versus magnitude. Two such curves were summarized by Hofmann, (1974). Figure 2-1 illustrates the better data of Ambraseys and Tchelenko (1968), which indicates a very wide range of rupture lengths versus magnitude. Figure 2-2 is from Algermissen et. al., (1969), whose data are restricted to the strike-slip San Andreas fault. The latter curve lies approximately along the upper bound of the Ambraseys and Tchelenko data. This suggests that for strike slip faults, much greater lengths of rupture are required on the San Andreas fault than for the entire available data set to generate the same magnitude earthquake. Hence, the higher effective stress across other kinds of faults may be a contributing factor to the generation of large magnitudes from short rupture lengths. This effect may also be observed in the data of Bonilla (1970).

Based on the above it appears that the strike slip earthquakes of the San Andreas system have large source dimensions and may have correspondingly lower effective stress.

The Diablo Canyon site would be in the near field of the postulated event, the distance to the source would be small compared to the size of the source. In this situation the energy available to contribute to peak acceleration is limited to the energy released in a short segment of fault rupture, the length of which equals the distance to the source (Brune, 1970). Thus, a large near field earthquake can be expected to produce smaller peak accelerations than would be indicated by:

(1) extrapolating from distant events where source size is not large compared to distance, or

(2) extrapolating from closer events of small magnitude with ~~small source dimensions~~.

Further, the design significance of peak acceleration is different for near field events. Instrumental records close to the source indicate relatively high values for the highest acceleration peak, with rapidly declining values for subsequent peaks. Further, the higher peaks often do not occur in sequence. This contrasts with recordings from distant events where subsequent peaks may be nearly as high as the highest peak. Because development of high levels of acceleration in response spectra is dependent on repeated pulses, effective acceleration can be lower relative to the maximum peak expected in the near field and yet provide an adequate representation of structural response.

Design spectra are mathematically related to Fourier amplitude spectra. Such a relationship for undamped design spectra was presented by Hudson, 1962. Fourier amplitude and phase spectra define a time function (in this case, the strong motion seismogram). Fourier amplitude spectra alone or the design spectra which may be derived from it, cannot define a unique time function. Rather, they define a family of such functions with various durations and peak amplitudes. In practice synthetic seismograms to test dynamic behavior of structural design may be made with a high amplitude and short duration which develop the same structural response or design spectra as longer lower amplitude seismograms which are more costly to use because of a longer required computer run time. The corollary is that a peak acceleration from a seismogram cannot be used to accurately set a Fourier spectra or design spectra. The use of peak accelerations to set design spectra is conservative but becomes overly conservative when only one or a few peaks are substantially greater than most of the high amplitude portion of the record. An example is the 1971 Pacoima dam record of 1.25 gs. A Regulatory Guide 1.60 design spectra which envelopes the actual calculated design spectra has an anchor point of about .75g. For example, the 1971 Pacoima accelerogram is from the M = 6.5 San Fernando earthquake. However, the Ground motion at the Pacoima dam, strong motion seismograph station appears to have been amplified by topography, structural response of the ridge and by breaking of the seismograph foundation rock and pier. Therefore, the

.75g enveloping design spectra is appropriate for an M = 6.5 earthquake only under circumstances identical to the Pacoima dam strong motion instrument. The Diablo Canyon Power Plant site is not on a ridge of rock. It is located on flat ground at the base of a hill. Topographic amplification is not predicted. There is no ridge of rock with its dynamic structural response to contribute to the motion. Cracked foundation rocks and churned ground was found on hilltops following the 1971 San Fernando earthquake. The Diablo Canyon Plant is not on a hilltop and hence is not likely to suffer cracked or broken foundation rock. A magnitude 6.5 earthquake a few kilometers from the Diablo Canyon Plant would, therefore, not produce a free field design spectra with a .75g anchor point. It would produce a design spectra anchored at a lower value. USGS Circular 672 recommends a peak acceleration of .90g and 1.15g for the near field area of an M = 7.5 earthquake. This value is less than the 1.25g peak of the Pacoima dam accelerogram recorded under peculiar conditions. Therefore, the .75g design spectra anchor for the proposed M = 7.5 earthquake on the Hosgri fault appears conservative.

There are no instrumental records of ground motion close to the source of earthquakes as large as magnitude 7.5. However, intensity data, based on observed effects and damage, are available for such events as well as for smaller quakes. 10 CFR 100 Appendix A requires that such data be considered. Correlations between acceleration and intensity have been made based on available data. Although there is a great deal of scatter in the correlations, they are useful in bounding the level of effective acceleration. We normally use the correlations of Trifunac and Brady (1975).

The 1906 San Francisco earthquake of magnitude 8.3 provides an example of a large strike-slip earthquake. In this case, Rossi-Forel intensity X or greater occurred only within about a mile and a half of the main rupture of the San Andreas fault. At 3 1/2 miles from the San Andreas fault Rossi-Forel intensities of IX and less were observed along the main break. This corresponds to the Modified Mercalli Intensity of VIII (USGS Circular 1279). The mean acceleration from the Trifunac and Brady curves for Modified Mercalli VIII is approximately .25g. It is difficult to determine the first and second standard deviations because of a lack of data. The data for MM VIII alone indicated a mean value for acceleration which is considerably less than that derived by the 1975 Trifunac and Brady straight line extrapolation from smaller intensities. However, using the straight line extrapolation, it appears that the second standard deviation of acceleration associated with MM VIII is about .54g which is very close to the original double design acceleration used for the Diablo Canyon Plant. The second standard deviation of acceleration would include virtually all the scattered accelerations observed for a given Modified Mercalli intensity.

The Trifunac and Brady 1975 second standard deviation value exceeds the largest acceleration which has been associated with MM VIII. Thus, available direct evidence does not support effective accelerations from the magnitude 8.3 on the San Andreas fault higher than about .54g at a distance of 3 1/2 miles from the fault.

Another example is the 1927 Point Arguello earthquake, also called the 1927 Lompoc Earthquake of magnitude 7 1/4. There is disagreement about the location of this earthquake and its mechanism. However, the possibility that it occurred on the Hosgri fault was one of the reasons for setting the magnitude for the postulated event. If the isoseismal map of the 1927 earthquake were moved northward along the Hosgri fault to the plant site, the highest observed intensity, at a distance of 3 1/2 miles from the fault, would be the same value as discussed above, Modified Mercalli VIII.

Based on the foregoing considerations, I consider 0.75g to be an acceptably conservative effective acceleration for reevaluating the Diablo Canyon units in consideration of a postulated earthquake of magnitutde 7.5 centered on the sector of the Hosgri fault nearest the plant site.

Further, the angle of approach to the structure of the high acceleration seismic waves is important. Work by Bouchon 1978 indicate that high amplitude strong motions near the source are caused by horizontally travelling "surface P waves". Bouchon 1976 modeled mathematically the 1971 San Fernando Earthquake. He determined that high amplitude high frequency pulses on the Pacoima dam strong motion record represented the Raleigh break out phase, also horizontally travelling. Therefore, although simple body waves and their reflections from a nearby fault plane would arrive at a site with various angles of incidence, peak acceleration pulses appear to be horizontally travelling.

Based on my analysis, I concluded that .75g is a conservative acceleration to reference a free field design (response) spectrum for the Diablo Canyon Nuclear Power Plant.

I hereby certify that the information above is true and accurate to the best of my knowledge.

Renner B. Hofmann

Subscribed and sworn to before

me this 11 day of November 1978

Notary Public

My Commission Expires July 1, 1982

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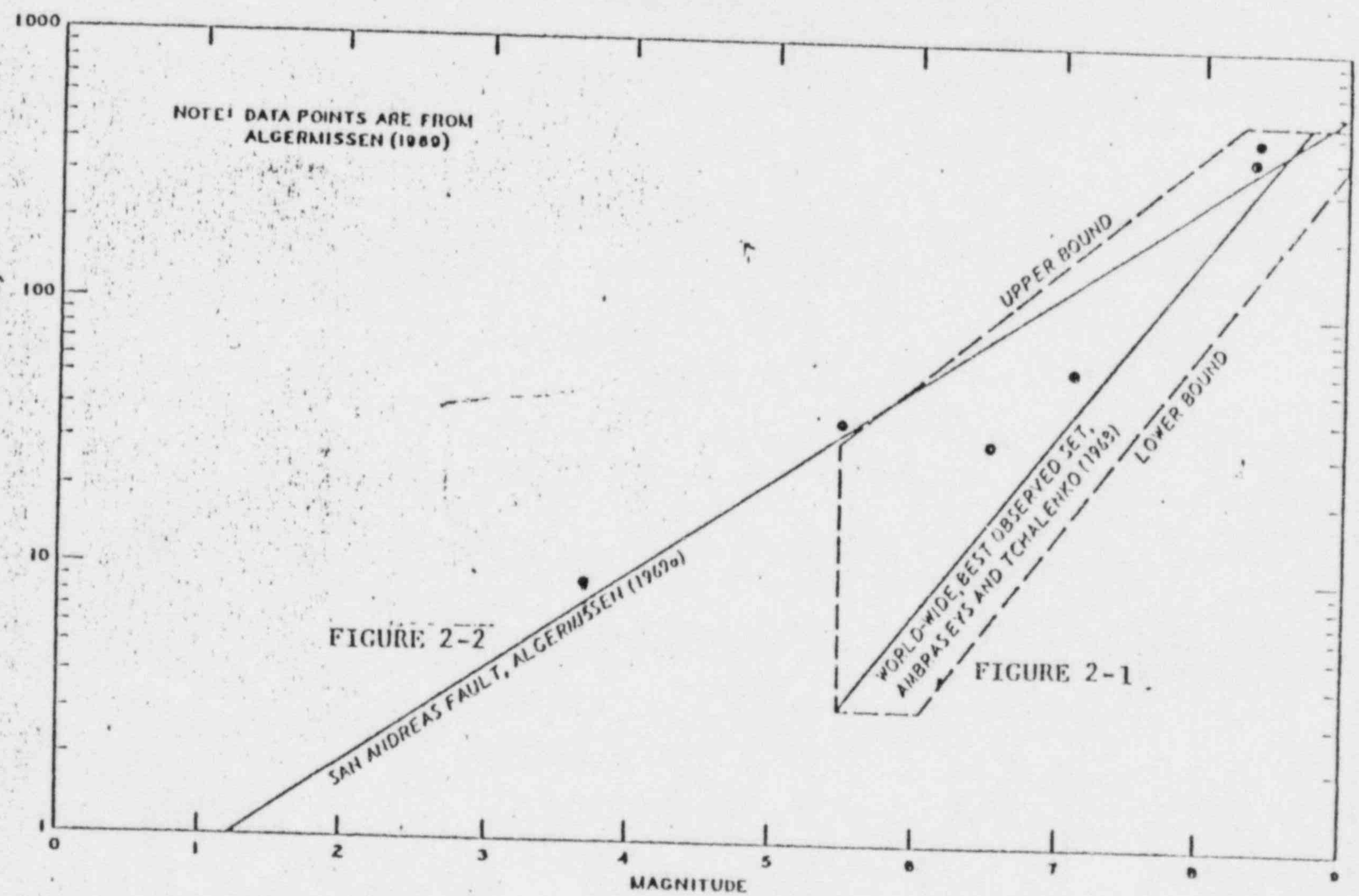

Fig. 1. Length of surface rupture versus magnitude

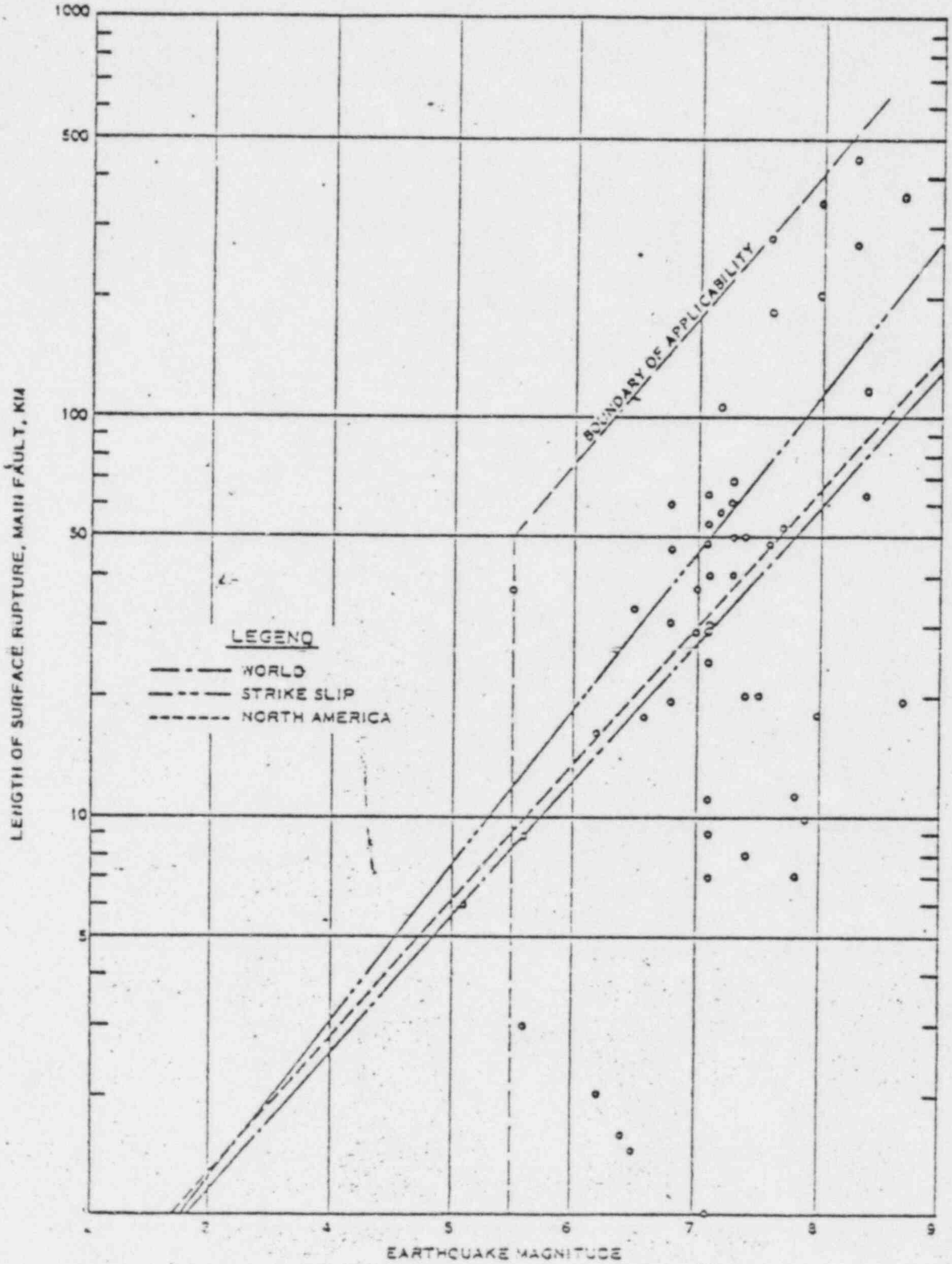

FIGURE 2-3 Length of surface rupture on main fault as related to earthquake magnitude. From Bonilla and Buchanan;[21] boundary of applicability added

CONTENTION 9

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

TESTIMONY OF RENNER B. HOFMANN

My name is Renner B. Hofmann. I am assigned to the Office of Standards Development of the United States Nuclear Regulatory Commission as seismologist. I have occupied this position since July 1978. I was the principal seismologist reviewer for the Diablo Canyon Nuclear Power Plant from October 1974 to July 1978. I was Leader of the Geology/Seismology Section in the Office of Nuclear Reactor Regulation from July 1976 to July 1978. My degrees include an M.S. in Seismology and a B.A. in Geology with a Minor in Mathematics. Attached is a copy of my curriculum vitae.

This testimony is in response to Intervenor's contention number 9 which read as follows:

> Do you contend that the strong (7.3M) earthquake recorded near the central California coast on November 4, 1927 took place on the Hosgri fault? If so, (sic) please identify the fault on which you contend this earthquake did take place.

To prepare my analysis, I began by reviewing the applicant's PSAR. I made site visits, met with the applicant, his consultants, U.S. Geological Survey staff and NRC consultants. I reviewed the intervenor's contentions, literature published by their consultants and other pertinent technical literature. I attended professional society meetings where topics of applicability to the Daiblo Canyon application were being reported or discussed. I visited the Shell Oil Company in Houston, Texas, to examine the proprietary Seismic Profiles used by Hoskins and Griffiths (1971) to identify the fault now known as the Hosgri fault. I prepared draft responses to the intervenor's contention, met with USGS representatives, legal staff and the Geoscience Branch Chief on several occasions. The Branch Chief subsequently modified and edited my response which now appears as the staff response of October 23, 1978.

In addition, my analysis revealed that the "felt" area of the 1927 earthquake is one fourth the size it should be for the 7.3 Richter magnitude assigned on the basis of Dr. Richter's correlation of felt area and magnitude (Richter 1958). Felt areas of California earthquakes are reported in the Earthquake History of the U.S. (Coffman and Van Hare (1971) as that area in which the earthquake was felt within the continental United States. Earthquake felt areas are generally centered over the source of the earthquake. In California, the San Andreas fault system is close to and parallels the Pacific Ocean shore. Splays of the San Andrea fault system continue to and cross the Mexican border. Consequently, the felt areas of many California earthquakes would continue into areas covered by ocean or into Mexico. These areas are not reported in the Earthquake History of the U.S. and must be compensated for by symmetrical extrapolation about the earthquake source. If the 1927 earthquake is assumed to have occurred on the Hosgri fault, an equal sized felt area seaward of the fault must be considered in addition to the land area on which the earthquake was felt. The generating fault must be considered to be nearly as distant as Byerley's 1930 epicenter to produce the correct felt area for the 1927 earthquake.

That the Hosgri fault is an unlikely source for the 1927 earthquake is also suggested by the total absence of reported seismicity until recent years. Attached is one sheet of a map summarizing all instrumentally determined epicenters for earthquakes over M = 3.5 and locations of major earthquakes in California prior to the availability of instrumentation, (Hill, Moore and Lao, 1962). A few small earthquakes have been relocated in the vicinity of the Hosgri fault (Hileman 1973 and Gawthrop 1975). Earthquakes of this size, M = 4.5 or less, are not detectable at great distance. The seismograph stations which recorded them were east of the epicenters. Without seismic stations also distributed west of the epicenters uncertainty in the relocations to a particular fault remain.

If these earthquakes are assumed associated with the Hosgri fault their numbers are too low to support the Hosgri fault as a source for the 1927 earthquake. For each succeeding whole magnitude smaller, 8 times as many earthquakes should be normally observed. Therefore, there should be 8 times as many M = 6.3, 64 times as many M = 5.3 and 512 times as many M = 4.3 earthquakes on the Hosgri fault as there are M = 7.3 earthquakes. The California Institute of Technology lists (Hileman 1973) has two M = 4.5 entries that could be associated with the Hosgri fualt and none of larger size. Thus, if the rate of magnitude 7.3 earthquakes is one per length-of-historic-record, there should be 64 M = 6.3 earthquakes and 512 M = 4.3 earthquakes. This is not the case. The instrumental record began about 1932. All earthquakes of M = 6.3 should have been located. None were located near the Hosgri fault. 1978 minus 1932 is 46 years. On this basis, the return period of an M = 7.3 earthquake should be greater than 46 X 64 or 2,944 years.

Further, as pointed out in PG&E's docketed material, the normal aftershock activity of an M = 7.3 earthquake should have continued from 1927 well into the 1930's with smaller aftershocks continuing for longer periods. Instrumentation installed in the early 1930's did not record such aftershocks that could be attributed to the Hosgri fault.

Based on my analysis, I conclude that it is extremely unlikely that the 1927 M = 7.3 Lompoc Earthquake occurred on the Hosgri fault.

I hereby certify that the information above is true and accurate to the best of my knowledge.

Renner B. Hofmann

Subscribed and sworn to before me this 11 day of November 1978.

Notary Public
My Commission Expires July 1, 1982

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