UNITES STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

TESTIMONY OF JAMES N. BRUNE

On Behalf Of

JOINT INTERVENORS

Regarding

APPEAL BOARD QUESTIONS 1, 4 (PARTIAL), AND 7

In The Matter Of

DIABLO CANYON NUCLEAR POWER PLANT, UNITS 1 & 2

Docket Nos. STN 50-275, 50-323 O.L.

AUGUST 8, 1980

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I. INTRODUCTION

My name is James N. Brune. I am Professor of Geophysics at the University of California at San Diego. My educational background includes a Bachelor of Science degree in Geological Engineering from the University of Nevada and a Ph.D. in Seismology from Columbia University. I have carried out a number of studies relating to earthquake source mechanism and strong motion in recent years. Currently I am conducting a study of the strong motion records resulting from the October 15, 1979 Imperial Valley earthquake. My study of the strong motion data resulting from the Imperial Valley earthquake is being funded by a grant from the National Science Foundation. Hence, I am very familiar with current and previous investigations of earthquake source mechanisms and strong motion data. My qualifications,

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* Joint Intervenors are: Scenic Shorelines Preservation Conference, Inc., San Luis Obispo Mothers for Peace, Ecology Action Club, Sandra A. Silver, and John J. Forster.

experience, and a list of publications are described in detail in an attachment to the testimony I presented to the Atomic Safety and Licensing Board during the Diablo Canyon seismic hearings in January, 1979. 1/

II. STATEMENT OF ISSUES

The purpose of my testimony today is to address Questions 1 and 7 proposed by the Atomic Safety and Licensing Appeal Board (Appeal Board) in ALAB-598 as follows:

A. (Question 1) "The October 15, 1979, Imperial Valley Earthquake (IV-79, M_L=6.4-6.9) provided an extensive set of strong motion records in the near field of a rather severe earthquake. The parties should compare the horizontal peak acceleration values recorded for various instrument positions with earlier predictions and compilations of such motion, e.g., those contained in the Final Safety Analysis Report (FSAR) on the Diablo Canyon Nuclear Power Plant, Amendment 50, Appendix D LL 11B, Figures 2, 3, and 4; and United States Geological Survey (USGS) Circular 795, Figures 4, 24, 47, and 48. Those comparisons should (if possible) address whether there is magnitude independence or a saturation effect for ground motion intensity in the near field of earthquakes."

B. (Question 7) "Intervenors (Brune Affidavit, p. 5) and the applicant (Frazier Affidavit, Para. 3) have suggested that the strong motion data obtained from stations along the direction of the Imperial Fault evidence the 'focusing' of earthquake motion. Yet, when the acceleration data of two such stations, El Centrol Array Numbers 6 and 7, are plotted as a function of distance from the fault (e.g., Blume Affidavit, Figures 1 and 2), the horizontal acceleration values fall well below the regression line mean for the 1 km distance. The vertical acceleration values are also lower than the mean on such a plot."

(Question 7 contd) "To the extent possible, the parties should analyze the seismic records for the IV-79 earthquake as they pertain to the focussing phenomenon and relate the results of such analyses to the likelihood that, in the event of an earthquake anywhere along the Hosgri Fault, focussing might result in amplified seismic motion at Diablo Canyon."

My testimony today also partially addresses Appeal Board Question 4, (the portion regarding the application of Regulatory Guide 1.60 to Diablo Canyon is not discussed herein) as follows:

C. (Question 4) "The magnitudes of vertical and horizontal acceleration values measured at IV-79 are generally comparable. (Mean values calculated at a distance of 5.8 km from the fault are virtually identical).....Should there be substantive and relevant analyses suggesting that vertical motion records do not reflect the true vertical motion, these should be provided."

III. DISCUSSION OF ISSUES

The Appeal Board in ALAB-598 granted Intervenors' motion to reopen the Diablo Canyon record to address nine questions drafted by the Appeal Board concerning the NRC review of Diablo Canyon Nuclear Power Plant, Units 1 and 2. The Appeal Board questions were in response to Intervenors' motion that new data obtained from the October 15, 1979 Imperial Valley earthquake cast a shadow on the adequacy of the Licensing Board's seismic analysis presented in the September 27, 1979 partial initial decision.

A. Horizontal Acceleration:

In my affidavit of February 29, 1980, I stated that the new data from the Imperial Valley earthquake of 1979 provide the only extensive set of data points for a single earthquake in the distance range relevant for the Diablo Canyon site.[2/]

As noted in my 1980 affidavit, the peak horizontal accelerations for the 1979 Imperial Valley earthquake were in general agreement with the 70% prediction intervals of Boore et al 1978 (USGS Circular 795) for an M=6.4 earthquake. For distances less than 15 km from the slip surface (less than the distances of the Boore curves, where there were few data before the IV-79 data points), the data indicate that acceleration increases with decreasing distance, but with a flattening slope at close distances.

Considering the inherent variability from earthquake to earthquake, it must be considered likely that future earthquakes of this same magnitude will in some cases generate higher accelerations. A magnitude 7.5 earthquake would be expected to generate still higher average accelerations. I indicated in my 1978 testimony before ASLB that about 10 earthquakes of magnitude near 7.5 would have to be recorded at close distances before we could be confident of expected accelerations. Frazier, in his 1980 affidavit (23 April, 1980) agrees that "Near-field data from several earthquakes should be considered to assess the variability in ground motion between earthquakes."

Based on the observations from the IV-79 earthquake, and on elementary physical considerations of such phenomena as focussing by rupture propagation and possible localized anomalously high stress drop, I conclude that there is no reason to assume that the accelerations observed for the IV-79

earthquake represent the maximum likely or conservative values for earthquakes of this magnitude. Rather, the most logical assumption (with low confidence because of the lack of sufficient data) would be that the accelerations for the IV-79 earthquake represent the average expected, and thus other earthquakes of the same magnitude would be expected to, in some cases, generate considerably higher average accelerations and in other cases, considerably lower average accelerations.

B. Horizontal Velocity

The peak horizontal ground velocities recorded for the IV-79 earthquake agree well with the curves of USGS Circular 795. For distances less than 15 km, the new data suggest extrapolations with an average velocity of about 40 cm/sec at a distance of about 7 km, with a corresponding 70% prediction interval velocity of about 75 cm/sec. For example, the Seismic Engineering Data Report for the IV-79 earthquake (Brady et al, 1980)[3/] gives peak (single component) velocities of 67.77 cm/sec at station 5 (4 km), and 77.65 cm/sec at station 4 (7 km) and 108.6 cm/sec at station 6 (1 km). Since this earthquake had a relatively small amount of slip compared to the 1940 El Centro earthquake of nearly the same or slightly smaller magnitude (see next section), it is likely that some earthquakes in this magnitude range will have considerably higher velocities at comparable distances. A magnitude 7.5 earthquake would be likely to have still larger velocities. Thus, a horizontal ground velocity of 61 cm/sec for the Diablo Canyon nuclear plant is

definitely not supported as a conservative value by the present data.

C. Comparison With 1940 Earthquake

The 1940 Imperial Valley earthquake, with nearly the same Richter local magnitude (6.4) as the IV-79 earthquake, had considerably larger displacements (up to 3 meters and greater) and thus a higher average stress drop. The high slip values occurred southeast of the only operating strong motion station. Further, the fault ruptured southeast, away from the strong motion station, focussing the energy in a direction where there were no strong motion recorders (see my ASLB testimony). Thus, the 1940 earthquake probably generated accelerations and velocities to the southeast of the epicenter that were higher than recorded in the IV-79 earthquake. Thus, the IV-79 earthquake is probably not a conservative example in terms of its stress drop, accelerations, and velocities (relative to its Richter local magnitude). This consideration emphasizes the lack of reliability, due to lack of data, in estimating likely near source values of acceleration and velocity.

Several persons have noted that damage was relatively low for the IV-79 earthquake even though recorded accelerations were relatively high (e.g., NRC staff response). Estimates of the Modified Mercalli Intensity in the near-field for the IV-79 are less than for the IV-40 earthquake (see attached comparison, Figure 1). Although this may in part be due to ambiguities in the Modified Mercalli Intensity scale, it is

clear that the damage from the IV-79 earthquake was considerably less than for the IV-40 earthquake, even though for the IV-40 earthquake the direction of rupture was away from the region where most buildings were located. This further supports the conclusion that the IV-79 earthquake is not a conservative example for its Richter magnitude. The fault length and average slip were both larger for the IV-40 earthquake. The surface wave magnitude for IV-40 (7.2 ± 1) is also larger than for IV-79 (6.9) reflecting in part the larger slip in IV-40 (James Lienkamper, USGS, personal communication).

D. Extrapolation to M=7.5

Concerning extrapolations of results for the IV-79 earthquake to higher magnitudes, all statistical correlations available in literature[1] indicate an increase in average peak accelerations, velocities and spectrum of ground motion with magnitude, with decreasing slope for larger magnitude. However, there are so few data available for earthquakes near magnitude 7.5 (only one good data point, from the Gazli earthquake), that there can be little confidence in these extrapolations, and thus large uncertainties exist in the ground motion spectrum and peak acceleration values appropriate for an M=7.5 earthquake. We can only be sure that on the average they will be higher for an M=7.5 than for an

[1]Aside from the correlations referenced in my testimony before ASLB, I have recently been shown results from a study by Ts'ao (1980) which also indicate increasing average peak accelerations with magnitude between M=6.5 and M=7.5.

M=6.5 earthquake.

E. Focussing

In ALAB-598, the Appeal Board stated that, "Intervenors (Brune affidavit, p.5).....have suggested that the strong motion data obtained from stations along the direction of the Imperial fault evidence the 'focussing' of earthquake motions." Actually, I suggested in my 1980 affidavit that focussing may have been operative in three other earthquakes (Santa Barbara, 1978, Gilroy, 1979, and Livermore, 1980).[2] The evidence for the effect of focussing on the observed accelerations in the case of the IV-79 earthquake is not clear to me at this time, and I believe that it is necessary to further analyze the data and the rupture mechanism before the effect of focussing can be assessed. It may turn out that the IV-79 earthquake is better represented as a sequence of multiple events than as a continuous rupture. Thus, it may be that focussing from a more continuous rupture would have led to even higher accelerations.

F. Vertical Accelerations

The magnitudes of vertical and horizontal accelerations near the fault (< 10 km) for IV-79 are generally comparable, but at some stations the vertical values considerably exceed the horizontal. Previous suggestions that

[2]Recently Boore and Porcella[5] (1980) have further documented the evidence for focussing in the Livermore, 1980 earthquake.

the vertical accelerations are less than 2/3 the horizontal appear not to apply very near faults. Even with the data from the IV-79 earthquake, there is not sufficient data to establish the expected average ratio of vertical to horizontal acceleration very near faults. I know of no evidence to suggest that vertical accelerations do not reflect the true vertical motion.

G. High Vertical Accelerations

To my knowledge, the explanations for the high frequency vertical accelerations of 1.74g at station 6 (1 km) and .93g at the El Centro differential array station (5 km) have not been finally established. There are several possible factors which may have led to increased accelerations at these sites, including effects of crustal structure, local amplification, localized high stress drop, and focussing by rupture propagation. Extensive analysis will be required before a final explanation is accepted. It seems probable that whatever the explanation, it represents a combination of phenomena which could only occur relatively close to the fault surface. However, until the final explanation is established there remains the possibility that such accelerations could occur at distances as far as several km from the fault trace and in particular at the Diablo Canyon site.

IV. CONCLUSIONS

The main conclusions of my testimony are as follows:

A. The recorded peak horizontal accelerations for IV-79 are in approximate agreement with the 70% prediction limits of USGS Circular 795 for an M=6.4 earthquake in the common distance range. For distances less than 15 km from the slip surface, the IV-79 data indicate that accelerations increase with decreasing distance, but with a flattening slope at close distances. The IV-79 earthquake is probably not a conservative example in terms of its stress drop, accelerations, velocities, and spectrum, relative to its Richter local magnitude.

B. There are too few data for earthquakes of M=6.5 to M=7.5 to establish the rate of increase of average peak acceleration or spectrum of ground motion going from M=6.5 to M=7.5. We can only be sure that on the average they will be higher for an M=7.5 than for an M=6.5 earthquake.

C. The effects of focussing have not yet been established for the IV-79 earthquake. Further analysis will be required. Focussing could have led to even higher accelerations than were observed in the IV-79 earthquake. There is indirect evidence that for the IV-40 earthquake, higher accelerations might have been generated (to the southeast) than were recorded for IV-79.

D. Data from the IV-79 earthquake indicate that in the near field, values of vertical acceleration can be considerably higher than 2/3 of the values of the horizontal accelerations.

In summary, the IV-79 data discussed in the foregoing and in my affidavit indicates that the Diablo Canyon design accelerations, velocities and displacements of 0.75g, 61 cm/sec and 24 cm, respectively, if assumed to represent true ground motion, are not established as conservative values for the M=7.5 design earthquake, since they were exceeded in the distance range of 3 to 7 km by the Imperial Valley earthquake with a magnitude of only approximately 6.6, the first earthquake of this size for which there were extensive near field recordings. The data also indicate that, in the near field, values of vertical accelerations can be considerably higher than 2/3 of the values of the horizontal accelerations.

We are not in the situation of having an extensive body of data on accelerations to be expected in the near-field (<10 km) of even M=6.5 earthquakes, let alone M=7.5 earthquakes. Methods of extrapolation have not been established as reliable. No reliable estimates of means or standard deviations can be made. Each new well-recorded earthquake can be expected to bring surprises (as did the IV-79 earthquake, with its high vertical accelerations) and thus significantly change our perceptions of what accelerations are probable and possible. In this situation, statements that certain assumed peak accelerations are "conservative" are necessarily cast in doubt, whereas the negative statement, that such accelerations have not been established as conservative, remains true.

LIST OF REFERENCES

1/ Testimony of James N. Brune entitled, "Contention 3 - Ground Motion," dated November 15, 1978, Diablo Canyon O.L. Proceeding Before the Atomic Safety and Licensing Board and hereinafter referred to as "1978 Testimony." The discussion and conclusions presented in my "1978 Testimony" are not repeated herein, but are adopted in their entirety as my current views for this testimony by this reference.

2/ Affidavit of James Neil Brune dated February 29, 1980, Diablo Canyon O.L. Proceeding Before the Atomic Safety and Licensing Appeal Board and hereinafter referred to as "1980 Affidavit." The discussion and conclusions presented in my "1980 Affidavit" are not repeated herein, but are adopted in their entirety as my current views for this testimony by this reference.

3/ Brady, A. G., V. Perez, and P. N. Mork. The Imperial Valley Earthquake, October 15, 1979. Digitization and processing of accelerograph records. United States Geological Survey Open File Report 80-703, (1980).

4/ Ts'ao, H. S. Correlation of peak earthquake ground acceleration in the very near field. SAN/1011-125. El Segundo, CA: Agbabian Assoc., Mar., (1980).

5/ Boore, David M. and Ronald L. Porcella. Peak acceleration from strong-motion records: a postscript. (To appear in Bulletin of the Seismological Society of America, December, (1980) as a letter to the editor.)

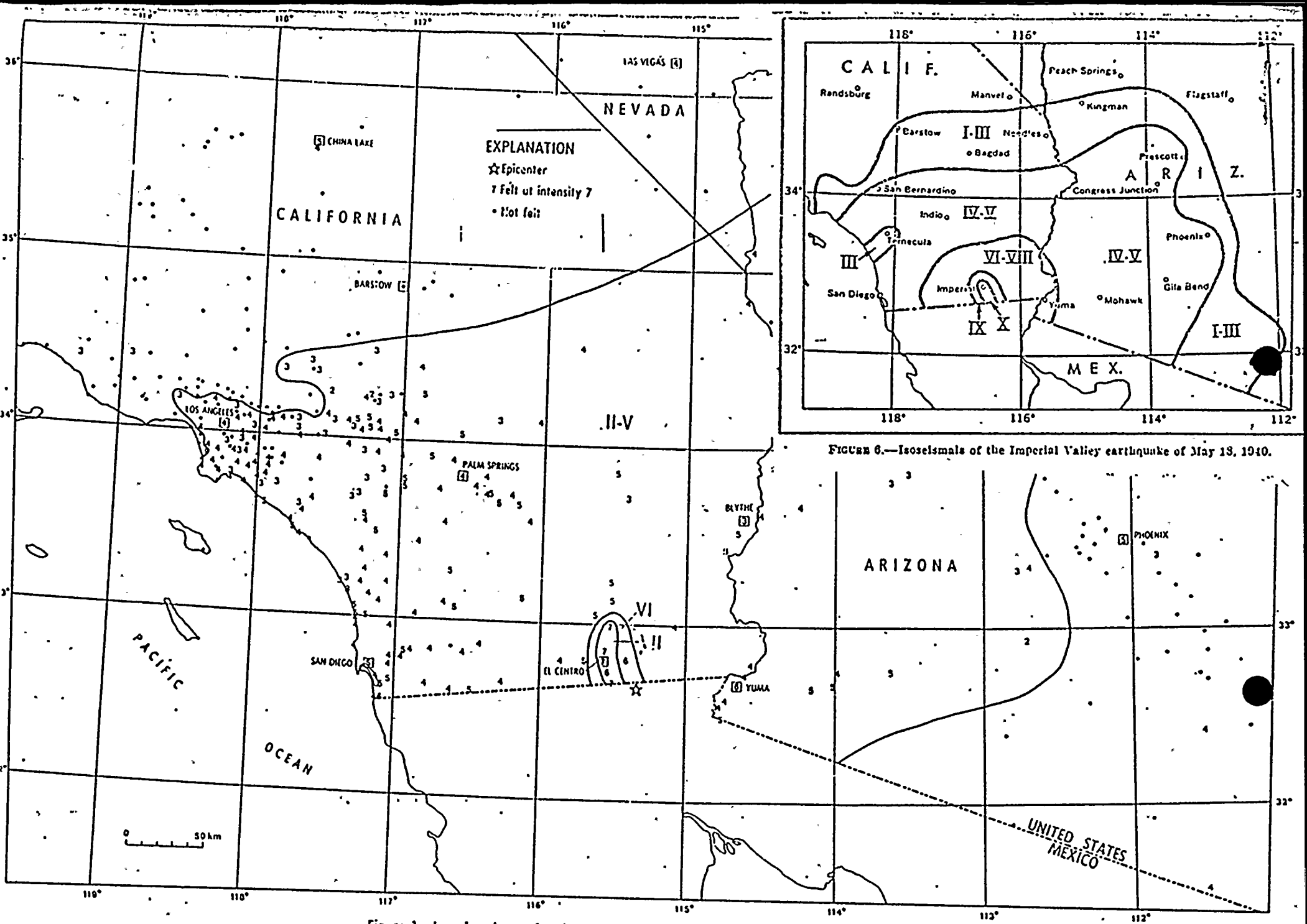

FIGURE 6.—Isoseismals of the Imperial Valley earthquake of May 18, 1940.

Figure 1.–Isoseismal map for the Imperial Valley earthquake of October 15, 1979.

Reagor and others, (1980)