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Report of the Evaluation of Maximum Earthquake and Site Ground Motion Parameters Associated with the Offshore Zone of Deformation San Onofre Nuclear Generating Station

PREPARED FOR

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REPORT OF THE EVALUATION OF MAXIMUM EARTHQUAKE AND SITE GROUND MOTION PARAMETERS ASSOCIATED WITH THE OFFSHORE ZONE OF DEFORMATION SAN ONOFRE NUCLEAR GENERATING STATION

0.0 SUMMARY

Detailed geologic, seismologic and earthquake engineering analyses and reviews have been completed for the San Onofre site to estimate the maximum earthquake magnitude that may be associated with the hypothesized offshore zone of deformation (OZD) (Figure 1), and the maximum ground motions that may be instrumentally recorded at the site during the maximum earthquake.

The PSAR and FSAR for SONGS Units 2 and 3 have presented extensive data regarding the geology, seismicity, and response characteristics of the site. Although no earthquake magnitude was estimated for the controlling earthquake source, a conservatively large earthquake was postulated for a fault 8 kilometers (5 miles) offshore from the site. As a result of these earlier studies, the Atomic Energy Commission (AEC) and its consultants agreed to a 2/3g design basis earthquake (DBE) and the spectral shape documented in their 20 October 1972 Safety Evaluation Report (SER).

Certain geologic models and assumptions have been defined by either the applicant or by the regulatory agency in the past and are important when estimating earthquake magnitudes. Based on the USGS and NOAA reports appended to the SER, the AEC concluded that the Newport-Inglewood zone of deformation (NIZD), the South Coast Offshore zone of deformation (SCOZD), and the Rose Canyon fault zone (RCFZ) cannot be disassociated and that they form a

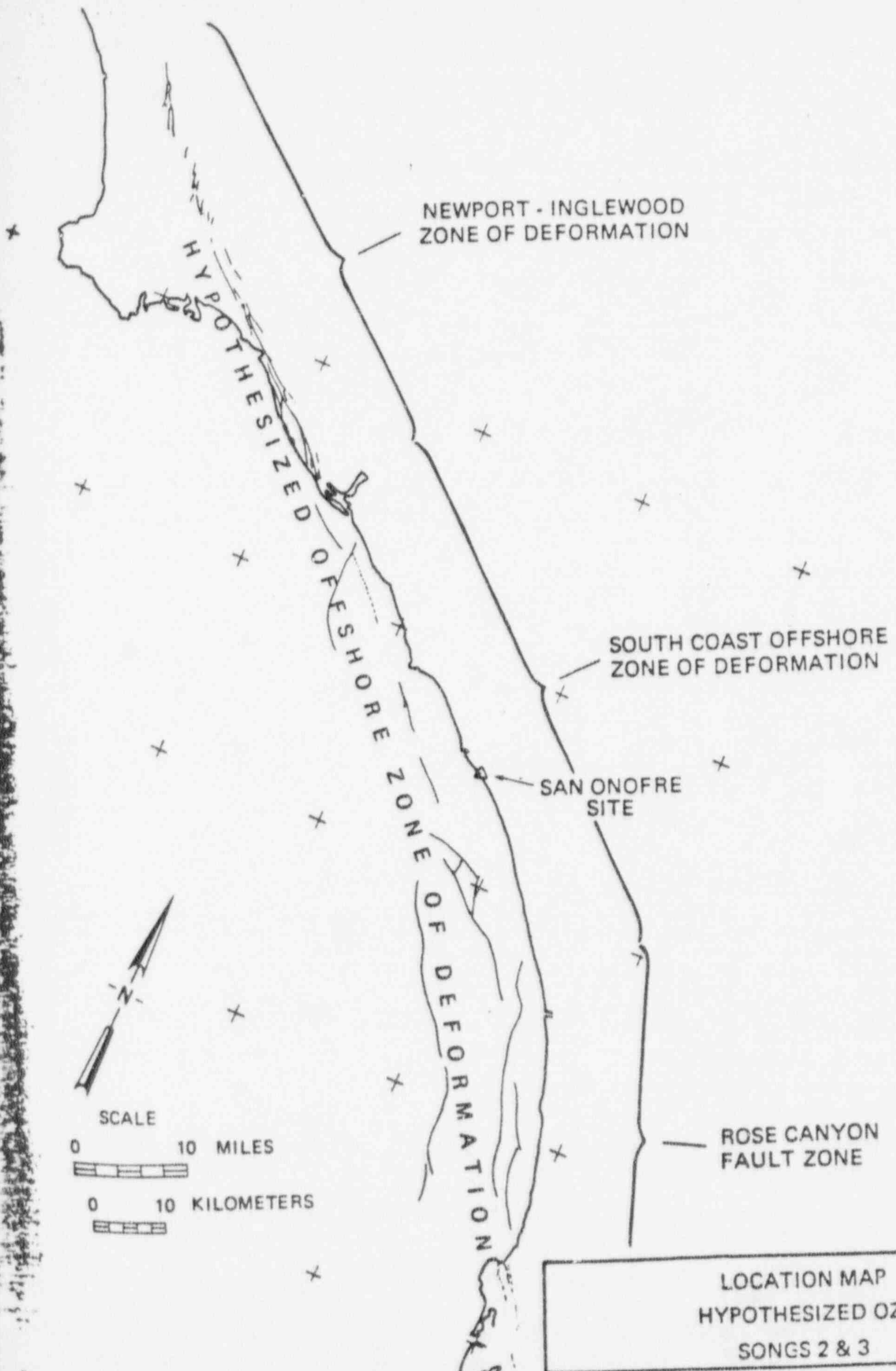
linear zone of deformation hypothesized to extend 240 kilometers (145 miles) from the Santa Monica Mountains south to Baja California. This zone, referred to as the hypothesized offshore zone of deformation (OZD) is about 8 kilometers (5 miles) west of the SONGS site. It was assumed to be capable of an earthquake having a magnitude commensurate with the length of the zone. The AEC further concluded that the hypothesized OZD, as described in the SER, would be the source of the DBE, and that the ground motions at the site from that earthquake would be accommodated in design by the 2/3g DBE and the spectral shape proposed in Section 2.5.2.6 of the FSAR.

The applicant concurs that the 2/3g DBE and spectral shape will accommodate potential effects of earthquake shaking at the site. The applicant suggests, however, that the hypothesized OZD is composed of three structural entities from north to south: the NIZD, the SCOZD, and the RCFZ. Interpretation of geologic data indicates that the hypothesized OZD is not continuous and, therefore, not capable of large earthquakes. A conservative approach was taken when evaluating site ground motions, in that the hypothesized OZD was considered as a whole, and capable of generating significant earthquake shaking at the site. This approach led to the development of the 2/3g DBE and spectral shape documented in Section 2.5.2.6 of the FSAR.

It is the purpose of the present study to estimate the maximum potential earthquake magnitude on the hypothesized OZD, to estimate the associated maximum instrumentally recorded ground motion values and to compare these values with the design basis parameters. The approach taken in this study is to model the hypothesized OZD according to the characteristics of the known-capable NIZD to the north.

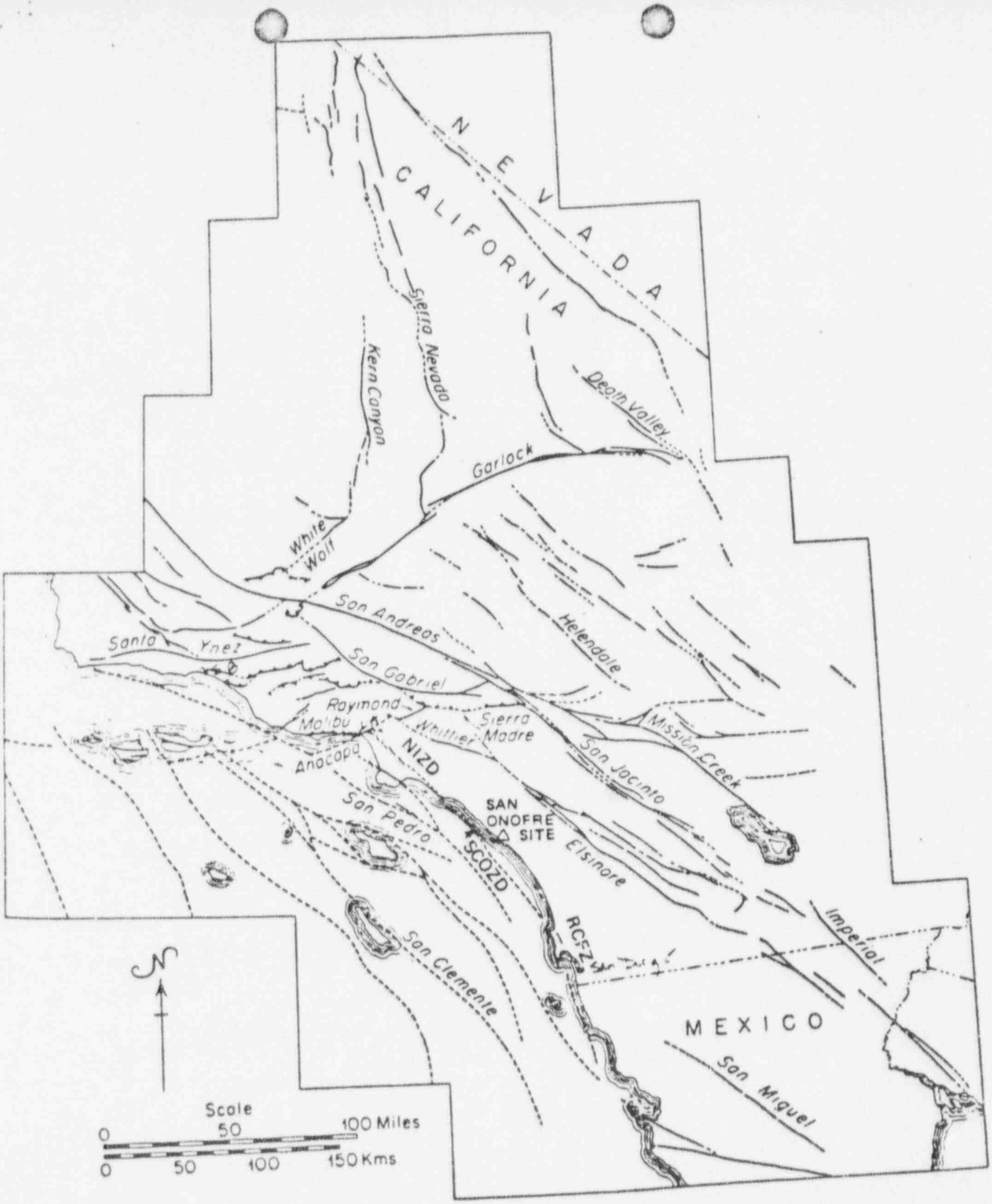
This study concluded that the maximum magnitude associated with the NIZD is estimated to be M 6-1/2. This conclusion is based on

an analysis of the geologic and seismologic environment of the hypothesized OZD and its similarity to other southern California faults, and on an empirical relationship between fault slip rate and earthquake magnitude. The conservatism of the above estimated maximum magnitude for the hypothesized OZD is demonstrated by the lower seismicity, the lower degree of deformation, and the lower stress environment of the hypothesized OZD compared to the NIZD. Given the estimated maximum earthquake magnitude of 6-1/2, the known local soil conditions at the San Onofre site, and the regional tectonic setting, 56 earthquake records were selected to correspond closely to the conditions of the estimated maximum earthquake and analyzed to develop instrumental mean (average) and 84th-percentile response spectra. A comparison between the computed 84th-percentile spectrum and the design spectrum shows that the design spectrum exceeds the instrumental spectrum at all periods.



LOCATION MAP
HYPOTHESIZED OZD
SONGS 2 & 3

Project No. 411001 Woodward-Clyde Consultants	Figure 1



(Modified from Allen et al, 1965; California Department of Water Resources, 1964a; Emery, 1960; Hill, 1916).

MAP OF MAJOR FAULTS IN SOUTHERN CALIFORNIA SONGS 2 & 3	
Project No. 411001 Woodward-Clyde Consultants	Figure 2

DEVELOPMENT OF MAXIMUM MAGNITUDE FOR THE OZD

1. Develop tectonic setting relating the OZD to the San Andreas and other faults using physical parameters.

2. Discuss conventional methods to develop maximum magnitude and compare them to slip rate to assess the most appropriate way to describe the relative activity of the OZD to other faults in the Southern California area.

3. Discuss the physical model of why slip rate versus maximum magnitude is viable for quantatively assessing maximum magnitude.

4. Present the results of a careful analysis of the slip rate data used in the empirical treatment of the slip rate-maximum magnitude relationship showing the best estimate developed in the June report and what carefully evaluated extremes in the data range would yield.

5. Develop a revised maximum magnitude-slip rate bounding line using a conservative interpretation of the data presented in 4.

6. Examine the NIZD as a model for the OZD for developing the maximum magnitude for the OZD.

7. Present a detailed statistical evaluation of the maximum magnitude-slip rate bounding line indicating the compatibility of the bounding line with the empirical data based on the observation period and the number of faults considered.

8. Evaluate the conservatism of the selected maximum earthquake for the OZD by comparing the estimated affects of such an earthquake (based on conventional relationships of surface rupture and displacement versus magnitude) to observed displacement and other geologic evidence of faulting.

OZD → OFFSHORE ZONE OF DEFORMATION

NIZD → NEWPORT-INGLEWOOD ZONE OF DEFORMATION

DEVELOPMENT OF SITE GROUND MOTION PARAMETERS

1. Summarize the work in the June 1979 report showing attenuation with distance of instrumental peak acceleration and response spectra.

2. Discuss the way in which the data were treated and compare with data treatment in USGS Circular 795.

3. Present the results of the extended source-path-site model examined since the presentation in September. The extended modelling incorporates empirical data from the Coyote Lake earthquake and the previously used Horse Canyon earthquake as well as keying on empirical data attenuation for M 4.5 to M 6 earthquakes and using a more site specific model.

4. Present the results of the 15 October 1979 Imperial Valley instrumental peak acceleration attenuation data. Specific comparisons will be made between the Imperial data and all soil sites (Appendix I of June report) and SONGS site specific data.

5. Discuss the effects of directivity and stress drop on the ground motions.

6. Present data on the effects of magnitude on peak acceleration both from the empirical data available and the modelling work.

7. Present the estimated maximum peak instrumental site accelerations consistent with the results of 4 and 6 and on the revised maximum magnitude from the slip rate-maximum magnitude work.

8. Present the progress of the work on instrumental response spectra for the revised maximum magnitude.

Modified Mercalli Intensity Scale	Description of Effects (Masonry A, B, C, and D Are Defined Below;ᵃ From Ref. 27)	Maximum Acceleration (g)	Richter Magnitude	Energy Release (ergs)
I	Not felt; marginal and long-period effects of large earthquakes evident		M2	10^{14}
II	Felt by persons at rest, on upper floors, or favorably placed		M3	10^{15}
III	Felt indoors; hanging objects swing; vibration like passing of light trucks occurs; duration estimated; might not be recognized as an earthquake	0.003 to 0.007		10^{16}
IV	Hanging objects swing; vibration occurs that is like passing of heavy trucks, or there is a sensation of a jolt like a heavy ball striking the walls; standing motor cars rock, windows, dishes, and doors rattle; glasses clink; crockery clashes; in the upper range of IV, wooden walls and frame creak	0.007 to 0.015	M4	10^{17}
V	Felt outdoors; duration estimated; sleepers waken; liquids become disturbed, some spill; small unstable objects are displaced or upset; doors swing, close, and open; shutters and pictures move; pendulum clocks stop, start, and change rate	0.015 to 0.03		10^{18}
VI	Felt by all; many are frightened and run outdoors; persons walk unsteadily; windows, dishes, glassware break; knickknacks, books, etc., fall off shelves; pictures fall off walls; furniture moves or overturns; weak plaster and masonry D crack; small bells ring (church, school), trees, bushes shake	0.03 to 0.09	M5	10^{19}

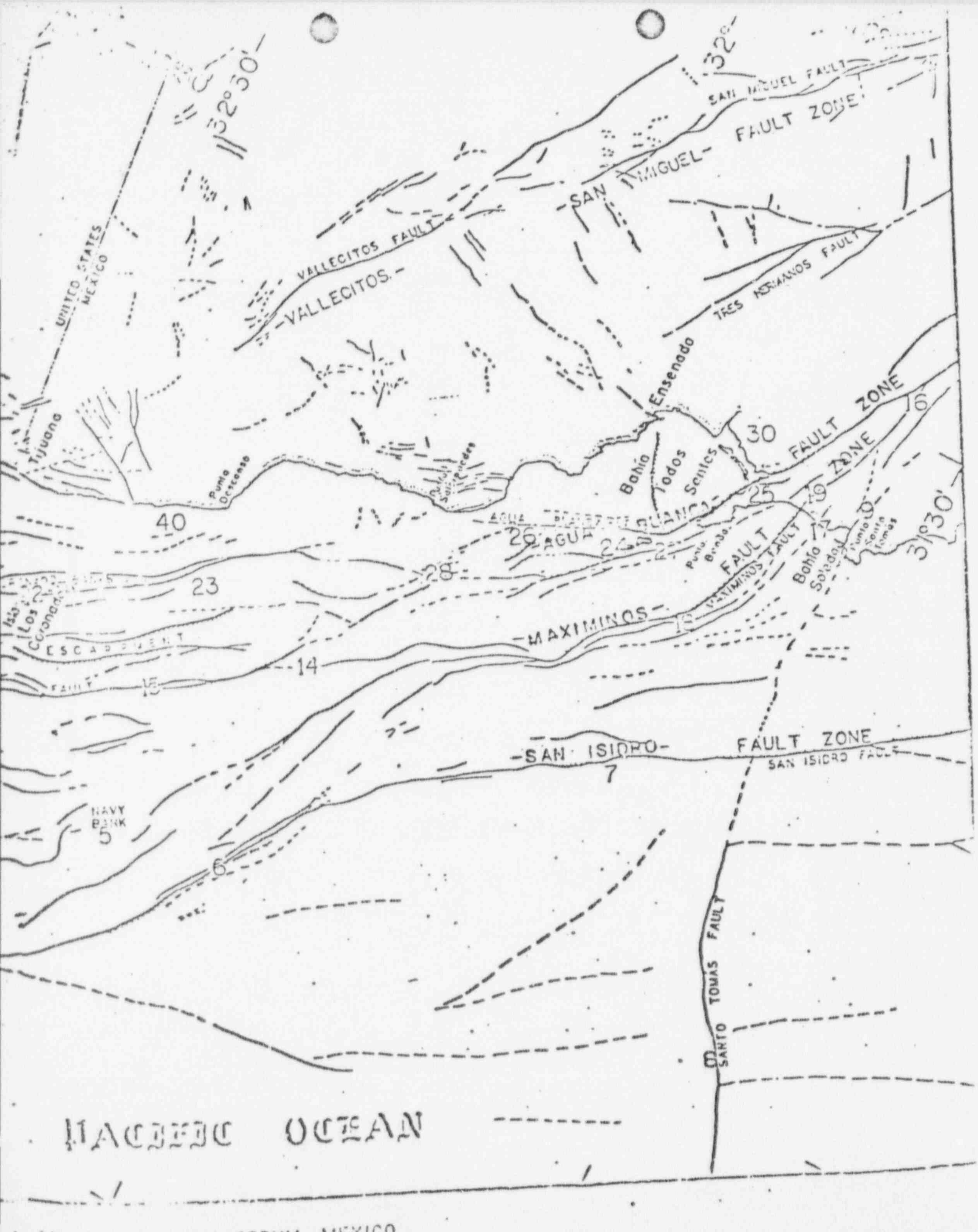
SAN ONOFRE #2 & #3 : 2/3 g - ACCELERATON

6 1/2 - MAGNITUDE

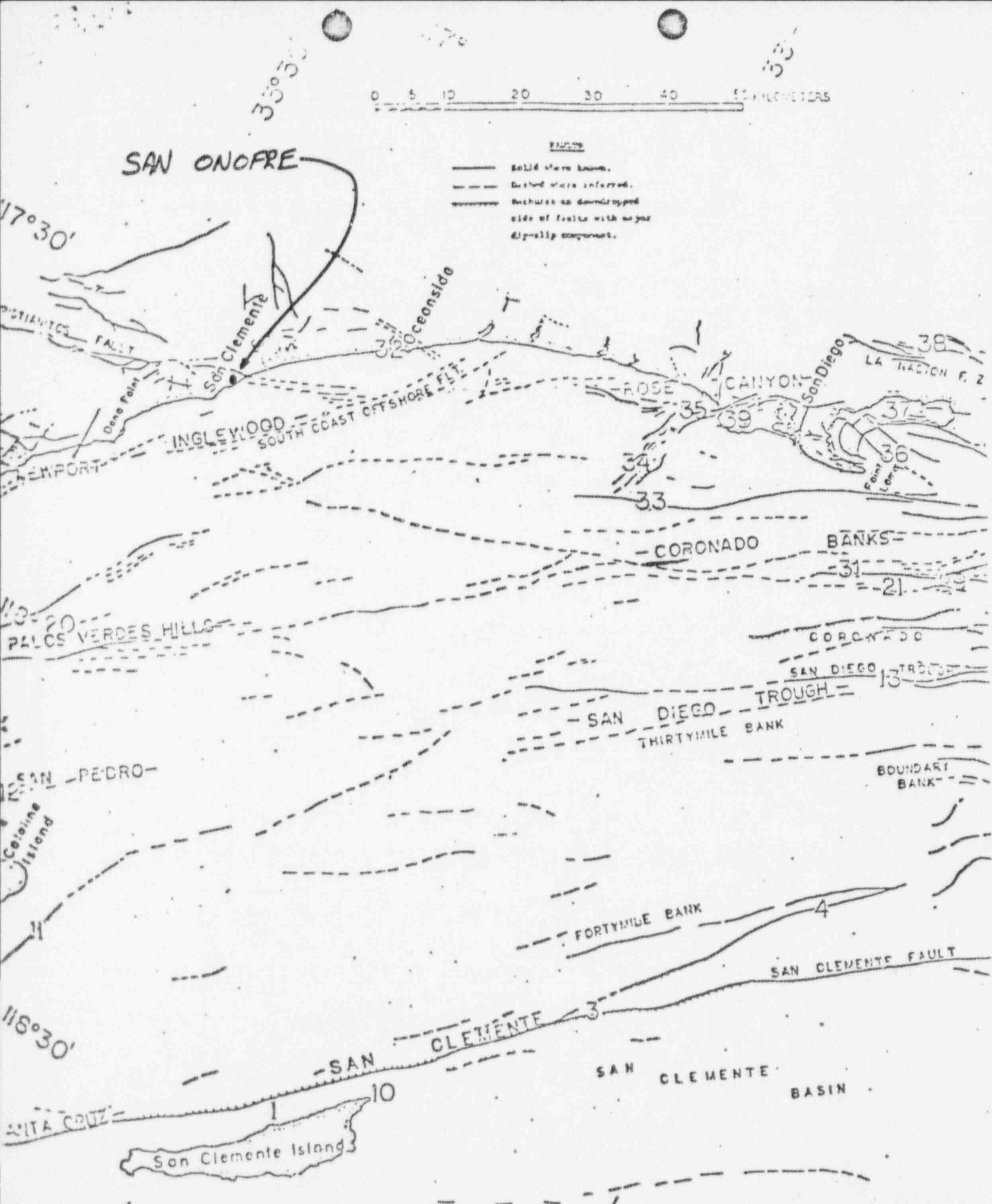
Modified Mercalli Intensity Scale	Description of Effects	Maximum Acceleration (g)	Richter Magnitude	Energy Release (ergs)
VII	Difficult to stand; noticed by drivers of motor cars; hanging objects quiver; furniture breaks; damage occurs to masonry D, including cracks; weak chimneys break at roof line; plaster, loose bricks, stones, tiles, cornices fall; some cracks appear in masonry C; waves appear on ponds, water turbid with mud; small slides and caveins occur along sand or gravel banks; large bells ring	0.07 to 0.22	M6	10^{20}
VIII	Steering of motor cars affected; damage occurs to masonry C, with partial collapse; some damage occurs to masonry B, but none to masonry A; stucco and some masonry walls fall; twisting, fall of chimneys, factory stacks, monuments, towers, and elevated tanks occur; frame houses move on foundations if not bolted down; loose panel walls are thrown out; changes occur in flow or temperature of springs and wells; cracks appear in wet ground and on steep slopes	0.15 to 0.3		10^{21}
IX	General panic; masonry D is destroyed; masonry C is heavily damaged, sometimes with complete collapse; masonry B is seriously damaged; general damage occurs to foundations, frame structures shift off foundations, if not bolted; frames crack, serious damage occurs to reservoirs; underground pipes break; conspicuous cracks appear in ground; sand an mud ejected in alluviated areas; earthquake fountains and sand craters occur	0.3 to 0.7	M7	10^{22}
X	Most masonry and frame structures are destroyed, with their foundations; some well-built wooden structures and bridges are destroyed; serious damage occurs to dams, dikes, and embankments; large landslides occur; water is thrown on banks of canals, rivers, lakes, etc.; sand and mud shift horizontally on beaches and flat land; rails are bent slightly	0.45 to 1.5		
XI	Rails are bent greatly; underground pipelines are completely out of service	0.5 to 3	M8	10^{23}
XII	Damage nearly total; large rock masses are displaced; lines of sight and level are distorted; objects are thrown into air	0.5 to 7	M9	10^{24}

ᵃ*Masonry A.* Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.
Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.
Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.
Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

FIGURE 9.21 Approximate relationships between intensity, acceleration, magnitude, and energy release. From T. F. Lomenick and NSIC staff, "Earthquakes and Nuclear Power Plant Design," Oak Ridge National Laboratory Report, ORNL-NSIC-28, 1970.



BAJA CALIFORNIA, MEXICO



FAULTING OFFSHORE SAN DIEGO AND