A MODEL FOR PREDICTING SEISMIC INTENSITY

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SYNOPSIS

A comparatively simple model of an earthquake and an observation-controlled scheme for specifying geologic ground conditions are used to predict seismic intensities for major California earthquakes. The high degree of agreement achieved between prediction and observation allows the drawing of several conclusions of significance to seismology and earthquake engineering.

INTRODUCTION

One aspect of "earthquake prediction" that is of great significance is prediction of the seismic intensities to be experienced at a given site as the result of expectable earthquakes. The purpose of this note is to report and comment upon the development of a mixed analytical/empirical computational procedure which provides the capability to predict accurately seismic intensity patterns for California earthquakes. The procedure uses a comparatively simple model of an earthquake plus estimates of the geological ground conditions based on relative levels of seismic ground motion. The earthquake model is based on a line source developed from the point source formulas of Kanai (1961) and Esteva and Rosenblueth (1964). The ground condition parameterization is based on data similar to that published by Borchardt (1970) applied to the published geological map of California.

The earthquakes studied are the San Francisco 1906, the Kern County 1952, and the San Fernando 1971 earthquakes. For illustrative purposes, we show in Figures 1 and 2 the predicted and observed Rossi-Forel intensities for San Francisco and Central California for the San Francisco 1906 earthquake.

This study indicates that, at least for California, comparatively simple fault and geological models suffice to predict quite accurately such intensity values.

Kanai, K. (1961). "An Empirical Formula for the Spectrum of Strong Earthquake Motions," Bull. Eq. Res. Inst., Vol. 39, 85-95.

Esteva, L. and E. Rosenblueth (1964). "Espectros de temblores a distancias moderadas y grandes," Boletin, Sociedad Mexicana de Ingenieria Sismica, Vol. 2, no. 1; revised by L. Esteva, personal communication with J.F.S., March 1969.

Borchardt, R.D. (February 1970). "Effects of Local Geology on Ground Motion Near San Francisco Bay," BSSA, Vol. 60, no. 1, 29-61

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Within this general conclusion, the analysis in the paper indicates that

1. Energy release in the damage-causing frequencies is essentially uniform along the entire surface of breakage (400 km for 1906 San Francisco earthquake).

2. Degree of water-saturation plays a profound role in influencing amplitude of ground motion on alluvium.

3. Intensity values from IV to X can be accurately predicted by use of control data based on small amplitude movements of seismic waves from a distant seismic event.

4. Procedures now used in generating published isosismal maps should be modified so as to make these maps of use and significance.

The apparent success of this investigation suggests that such an analysis can be used to predict intensity values to be expected from a large earthquake anywhere in California, can be used to predict the maximum intensities to be expected at any given site in the state based on expected rates and sizes of earthquakes and can be convolved with seismicity data to predict expected recurrence times of given intensity values at any given site. The necessary geologic factor characterization would be obtained by a systematic program of observation of relative seismic ground motion throughout the state. It is not too much to expect that ground condition values expressed in intensity units should be publicly available for the entire state. Perturbation and refinement of the fault model should allow application of the techniques to other areas.

We feel that our analysis has progressed to the point where we can assert that we have demonstrated the feasibility of accurately predicting seismic intensity patterns. We would, of course, agree that further refineme: in describing ground characteristics on a spectral basis, and in analytical description of the earthquake source are desirable, but these will result, at least for California earthquakes, in only small and localized changes in the predictions of our present model.

Predictions for future earthquakes cannot be based on the data on past earthquakes due to the demonstrably inadequately interpreted intensity data in the reports and associated maps of past earthquakes and due to the fact that the set of observed large earthquakes is certainly not expressive of potential large earthquakes in California. One of the major contributions of our procedures is that they allow accurate prediction of intensity patterns for expectable but as yet unexperienced major earthquakes, thus allowing more meaningful planning by authorities. By convolving such intensity patterns with the characteristics of buildings within an area and with a table expressing mean damage as a function of building type and seismic intensity, a quite accurate prediction of regional and local dollar damage for a given earthquake could be obtained.

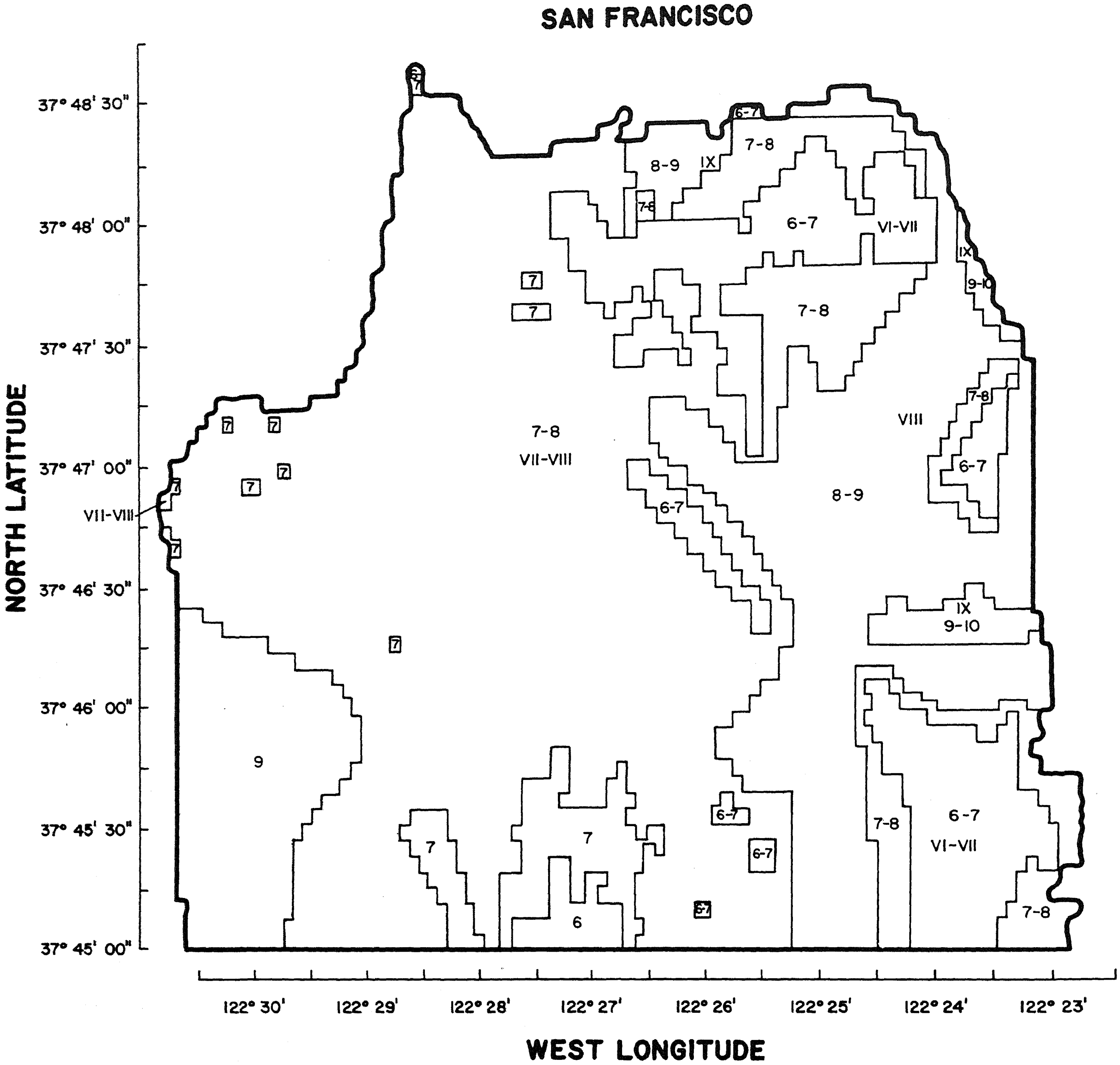

Figure 1. Predicted (Arabic Numerals) and Observed (Roman Numerals) Intensity Values in San Francisco - 1906 San Francisco Earthquake

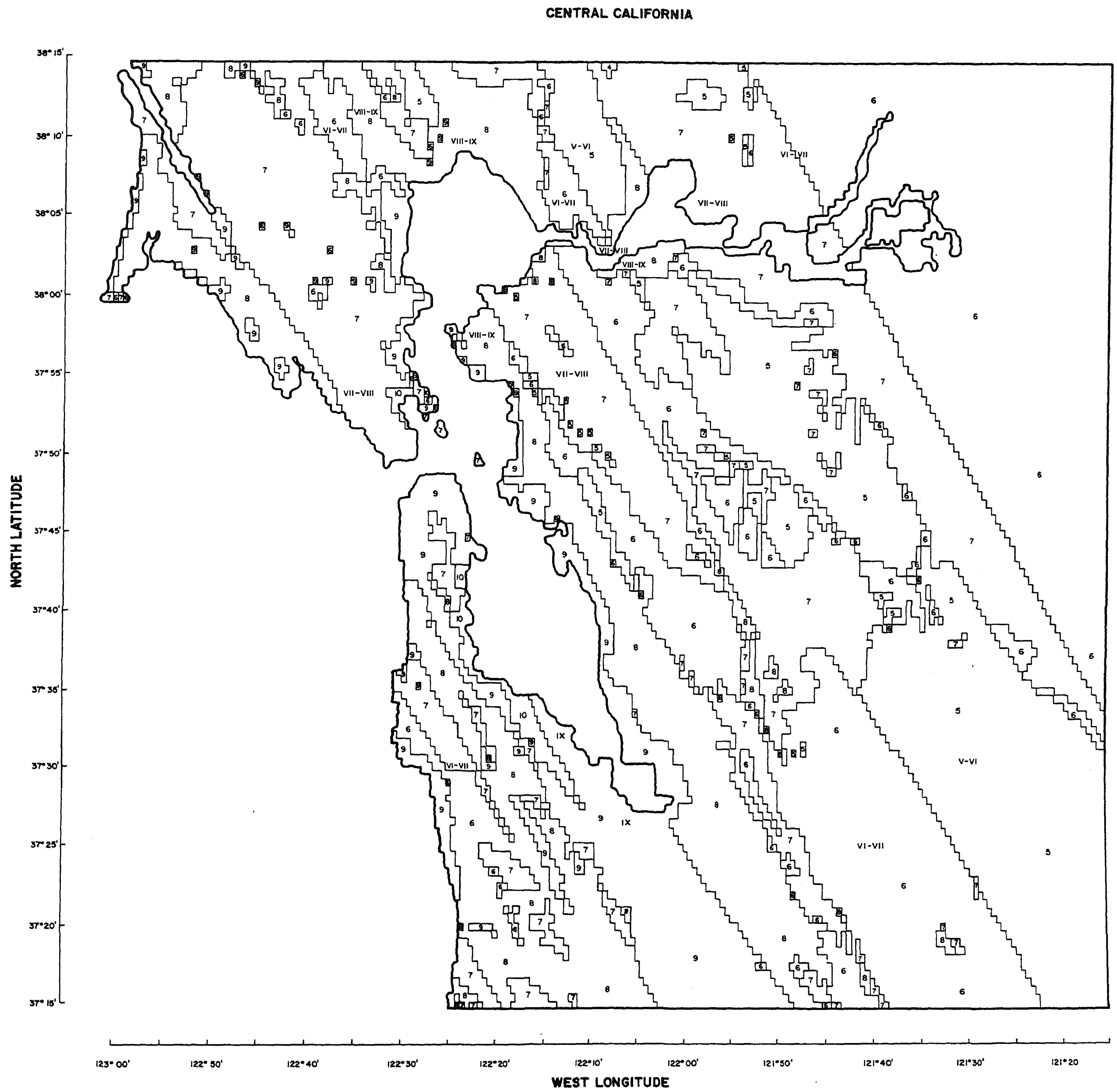

Figure 2. Predicted (Arabic Numerals) and Observed (Roman Numerals) Intensity Values in Central California - 1906 San Francisco Earthquake