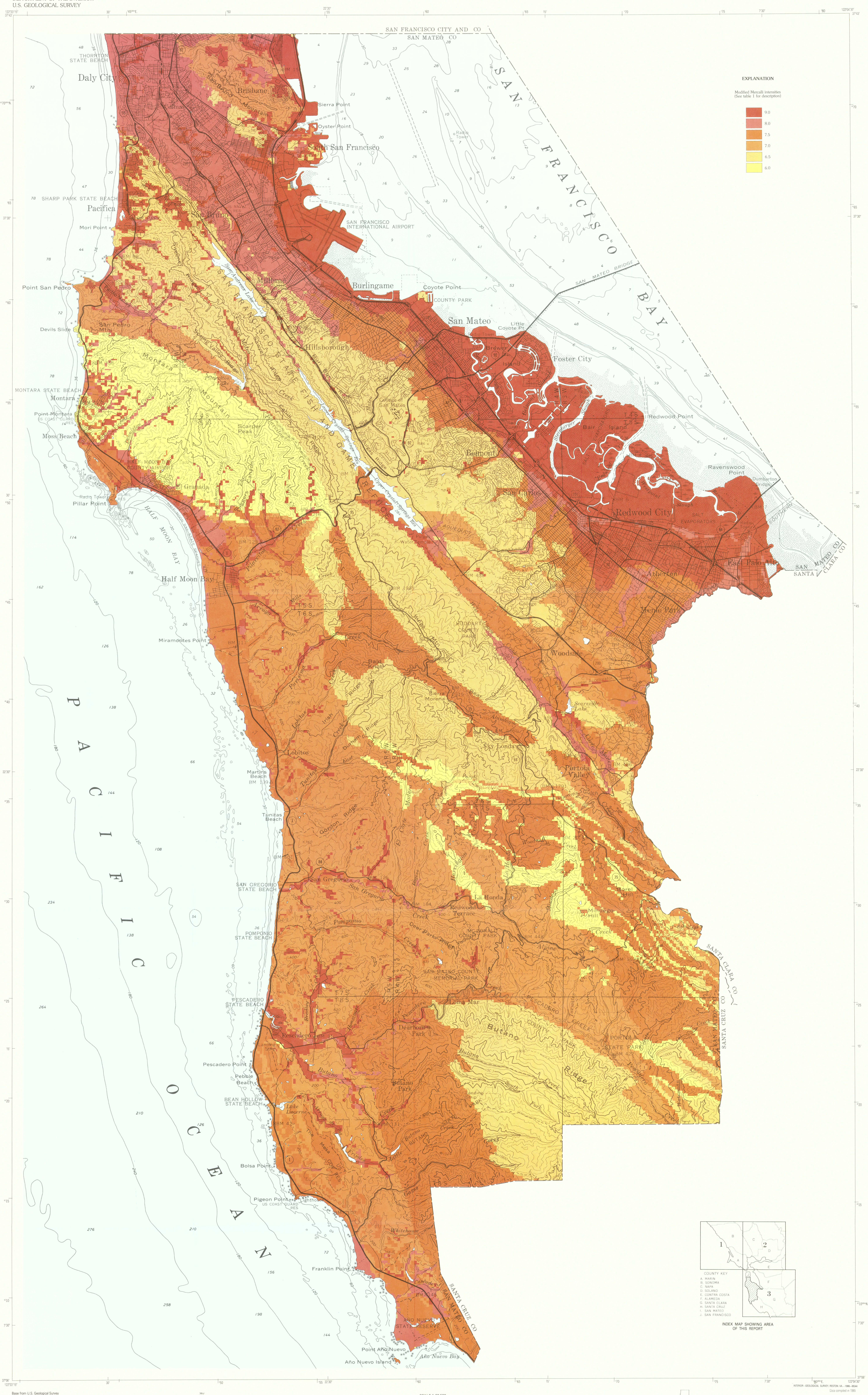

Base from U.S. Geological Survey San Francisco Bay Region, sheet 3, 1:125,000, 1970. Park boundaries revised 1981. 5000-meter Universal Transverse Mercator grid ticks, zone 10

SCALE 1:62 500

CONTOUR INTERVAL 200 FEET
DOTTED LINES REPRESENT 40-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER

INTRODUCTION

This map presents the predicted intensity of ground motion in San Mateo County, California, for a repeat of the 1906 San Francisco earthquake (magnitude 8.2-8.3). The units used are Modified Mercalli Intensities VI through IX (Wood and Neumann, 1931). These units are defined in terms of effects on people, structures, and natural surroundings. Table 1 presents an abridged version of the definitions of all Modified Mercalli Intensities, the full definitions being available in the reference cited above.

METHOD OF PREDICTING SEISMIC INTENSITIES

The procedures followed in calculation of the Modified Mercalli shaking intensities shown on the map are fully described in Evernden and others (1981) and Evernden and Thomson (1985). They are the identical procedures used for the intensity maps supplied to the California Division of Mines and Geology for use in their study of a repeat of the San Francisco 1906 earthquake, Davis and others (1982).

A brief summary of the procedures of calculation is as follows. The ingredients of the intensity modeling technique are (1) a law expressing the rate of attenuation of intensity-related seismic waves in the region to be investigated; (2) a correlation of geologic ground condition (saturated alluvium is used as the reference ground condition) and expected relative intensity; (3) a map giving the distribution of the several defined seismic ground conditions throughout the region to be investigated and; (4) a mathematical model of the earthquake source (including location, length of break, and depth of focus), plus a scheme of calculation that conceptually radiates energy from each segment of the fault, attenuates each increment according to element 1, calculates a quantity intended to simulate the root-mean-square (RMS) acceleration over a time window of 10 to 20 seconds (matter of choice) centered on the strongest arrival (that is, from nearest point on the fault), converts this RMS acceleration into a predicted intensity on saturated alluvium, and, by using the data in elements 2 and 3, calculates the predicted intensity for the site ground condition. The present computer model can provide either Rossi-Forel or Modified Mercalli Intensities.

ASSUMED SEISMIC GROUND CONDITION

Correlation of geologic ground condition with seismic shaking ground condition (expected intensity relative to saturated alluvium) is an important step in the intensity-prediction procedure. Two complementary procedures have been used in the past. In earlier papers, we followed Borcherdt (1970) in achieving intercalibration by means of the relative amplitudes of seismic waves recorded at sites on various rock and sediment types in the San Francisco Bay region. Because Borcherdt's data were not correlated with depth to water table, we followed Medvedev (1962) in decreasing the predicted intensity by one unit if the water table was known to be at a depth of 10 m or more in Quaternary alluvium. No adjustment for depth to water table is made in any other materials. For the present map, we established the geologic ground condition equivalency between the geologic units of Brabb and Pampeyan (1983) for San Mateo County and those used in previous studies of the San Francisco Bay region (Evernden and others, 1981; Evernden and Thomson, 1985). We then assigned the appropriate seismic ground condition (or relative intensity values) from the previous studies.

Table 2 presents the relative intensity values assigned to the geologic units of Brabb and Pampeyan (1983). Some of these assignments are based upon less than adequate data. For example, the alluvial deposits lying upon the wave-cut terraces along the western part of San Mateo Count (Qmt) are assigned a relative intensity value of −1.5, a value which effectively assumes such deposits to be thin and to have only small effect on intensity values, the underlying rock of appreciable strength being assumed to exert the dominant control on expected intensities. Such was the situation in the areas overlain by thin sheets of sand in the western parts of San Francisco during the 1906 earthquake. However, the Qmt marine terrace deposits in San Mateo County range from very few feet to greater than 100 ft in thickness with percent of water saturation varying markedly. Therefore, the intensity values given on the map are expected to be generally correct, but variations in thickness and water content of Qmt deposits locally could lead to somewhat higher intensities.

The map of Brabb and Pampeyan (1983) is sufficiently detailed to shown modern alluvial deposits in nearly all of the stream drainages in the western part of the county. We assumed all such material to behave as saturated alluvium, thus predicting the highest possible shaking intensities. Because of the narrowness and thinness of many of these deposits, such predictions are probably exaggerated estimates of expected intensity for many of these localities. More detailed mapping of the alluvium and better hydrologic data would improve intensity estimates in critical areas.

RESULTS AND CONCLUSIONS

The change of shaking intensity with distance from the San Andreas fault on uniform ground condition is so small for the postulated earthquake within the limits of San Mateo County that the predicted intensity map approximates a redrawn geologic map with mapped units defined in shaking terms rather than in conventional geologic terms. The highest predicted intensities (Modified Mercalli IX) are on the younger bay muds and artifical fill along the shore of San Francisco Bay (Foster City and other communities on such material), on a few alluvial deposits along the course of the San Andreas fault, and along the numerous stream channels that have modern alluvial deposits within them. The lowest predicted intensity values (VI) are on the granitic and metamorphic rocks of Montara Mountain (Kgr and m) and on scattered volcanic deposits (Tpm, Tmb, Tuv, and Kjv).

Because the higher shaking intensities are defined in terms of damage to structures, and because the capability to accurately predict intensities has been demonstrated (Evernden and others, 1981), the prediction of intensity constitutes the prediction of expected level of damage to many structures, most particularly to the wood frame homes common in California. Examples of prediction of expected level of damage to structures of various sorts as the result of a large southern California earthquake are given by Evernden and Thomson (1985).

It is important to note that the units of the Modified Intensity Scale as given in table 1 are defined in terms of pre-1930 structures. Building codes and practice have improved greatly since promulgation of the Modified Mercalli Intensity Scale in 1931 and recently built structures in California generally behave far better than suggested in table 1. In particular, data of recent California earthquakes indicate that post-1940 wood-frame construction practice generally achieves a protection equivalent to a decrease of 1 to 1.5 intensity units (Evernden and Thomson, 1985). Thus, when using the intensity predictions of map for estimation of expected level of average damage to post-1940 wood frame structures, one should enter table 1 with an intensity value at least one unit less than indicated on the map.

Another important point to understand is that the predicted intensities on the map relate only to shaking of structures, not to ground failure. Because Modified Mercalli Intensities of X and above are defined primarily in terms of ground failure, and because ground shaking effects are explainable in terms of intensities of IX or less, no intensities of X or higher are shown on the map. Correlation of expected intensity, ground characteristics, and ground slope can serve to predict many aspects of ground failure (for example, see Wieczorek and others, 1985). However, these matters are not addressed by the present map or discussion.

Differences in predicted intensities between this map and the maps in Davis and others (1982) result from use of different geologic maps to define ground conditions. The geologic map used for this study is the 1:62,500-scale geologic map of San Mateo County (Brabb and Pampeyan, 1983). That map was digitized on a grid size of 100 by 100 m. The geologic map used by Davis and others was the much more generalized 1:250,000-scale State Geologic Map (Jennings and Burnett, 1961), the digitization having been performed on a grid size about 100 times larger in area (1.5 by .5 minute) than used by Brabb and Pampeyan. Thus, there is far greater detail on the present predicted-intensity map than on the map by Davis and others.

ACKNOWLEDGMENT

Robert K. Mark, U.S. Geological Survey, kindly provided the geologic map of San Mateo County in digital format; converted fault coordinates from latitude and longitude to Universal Transverse Mercator coordinates so that the fault information could be combined with the geology; converted the combined data in digital form to an image for display on a graphic terminal; and produced the tape that was used to make the color-separation negatives used in printing of the map.

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Table 1—*Modified Mercalli Intensity Scale of 1931*
[Abridged; Wood and Neumann (1931)]

I. Not felt except by a few under especially favorable conditions.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Building shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Table 2.—*Correlation of Geologic Units and Ground Condition Units*
[Column 1 (GMU): Symbol of geologic map unit (from Brabb and Pampeyan, 1983; Wieczorek and others, 1985). Column 2: Name of geologic unit. Column 3 (GCU): Ground condition shaking unit assigned (as in Evernden and others, 1981; Evernden and Thomson, 1985). Column 4 (δI): Intensity value relative to saturated alluvium (Evernden and others, 1981; Evernden and Thomson, 1985)]

GMU	Unit name	GCU	δI
	Category A — Crystalline rocks and well-cemented sandstones		
Tmb	Mindago basalt and related volcanic rocks	H	−2.7
Tb	Butano Sandstone	C	−2.2
Tptu	Tunitas Sandstone Member (of the Purisima Formation)	D	−1.8
Tlo	Lompico Formation	D	−1.8
Tvq	Vaqueros Sandstone	C	−2.2
Tpm	Page Mill Basalt	H	−2.7
Tuv	Unnamed sedimentary and volcanic rocks	H	−2.7
m	Marble and hornfels	A	−3.0
fg	Greenstone (of the Franciscan assemblage)	C	−2.2
fm	Metamorphic rocks (of the Franciscan assemblage)	B	−2.6
fl	Limestone (of the Franciscan assemblage)	B	−2.6
fcg	Conglomerate (of the Franciscan assemblage)	C	−2.2
fs	Sandstone (of the Franciscan assemblage)	C	−2.2
KJv	Unnamed volcanic rocks	H	−2.7
KJs	Unnamed sandstone	D	−1.8
Kgr	Granitic rocks of Montara Mountain	A	−3.0
Kpp	Pigeon Point Formation	D	−1.8
	Category B — Unconsolidated and weakly cemented sandstones		
Qyf	Coarse-grained alluvial fan deposits	L	−1.0
Qs	Sand dune and beach deposits	L	−1.0
Qc	Colma Formation	G	−1.0
Qof	Coarse-grained older alluvial fan and terrace deposits	F	−1.5
Qmt	Marine terrace deposits	F	−1.5
Tpsg	San Gregorio Sandstone Member (of the Purisima Formation)	D	−1.8
Tb	Butano(?) Formation	D	−1.8
Tsm	Santa Margarita Sandstone	F	−1.5
Tus	Unnamed sandstone	F	−1.5
Tss	Unnamed sandstone, shale, and conglomerate	D	−1.8
	Category C—Shales and clays		
Qyfo	Fine-grained younger alluvial fan deposits	J	0
Qb	Basin deposits	J	0
Qcl	Colluvium	J	0
Qm	Bay mud	J	0
Qal	Alluvium	J	0
Qob	Fine-grained older basin and alluvial fan deposits	L	−1.0
Qaf	Artifical fill	J	0
QTs	Santa Clara Formation	F	−1.5
QTm	Merced Formation	G	−1.0
Tp	Purisima Formation, undivided	D	−1.8
Tpt	Tahana Member (of the Purisima Formation)	D	−1.8
Tpl	Lobitos Mudstone Member (of the Purisima Formation)	D	−1.8
Tpp	Pomponio Mudstone Member (of the Purisima Formation)	D	−1.8
Tls	Lambert Shale and San Lorenzo Formation, undivided	F	−1.5
Tsl	San Lorenzo Formation, undivided	D	−1.8
Tla	Lambert Shale	F	−1.5
Tst	Twobar Shale Member (of the San Lorenzo Formation)	D	−1.8
Tsr	Rices Mudstone Member (of the San Lorenzo Formation)	D	−1.8
Tm	Monterey Formation	F	−1.5
Tsc	Santa Cruz Mudstone	F	−1.5
Tbs	Shale in Butano Sandstone	D	−1.8
sp	Serpentinite	C	−2.2
Ksh	Unnamed shale	D	−1.8
KJf	Franciscan assemblage, undivided	C	−2.2
fsr	Sheared rocks (of the Franciscan assemblage)	C	−2.2
fc	Chert (of the Franciscan assemblage)	C	−2.2

MAP SHOWING PREDICTED SEISMIC-SHAKING INTENSITIES OF AN EARTHQUAKE IN SAN MATEO COUNTY, CALIFORNIA, COMPARABLE IN MAGNITUDE TO THE 1906 SAN FRANCISCO EARTHQUAKE

By
Jean Marie Thomson and Jack Foord Evernden

1986