INTENSITY DISTRIBUTION AND SOURCE PARAMETERS FROM FIELD OBSERVATIONS

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INTRODUCTION

The earthquake of February 4 in Guatemala was felt over an area of at least 100,000 km^2. It originated on the Motagua River Valley to the east of Los Amates and propagated west along the Motagua fault through Gualán and El Progreso to Chuarrancho (details of the surface faulting mapping are given by Plafker and others, this report). The sense of motion from field observations as well as from instrumental seismic determination (Dewey and Julian, this report) is a left-lateral strike-slip fault.

This paper is a preliminary report on the earthquake-damaged area studied during the period February 6–22. The purpose was to obtain information in Guatemala City and along the Motagua fault area to delineate the distribution of intensities (Modified Mercalli), damage to adobe-type structure, strong motions, and other related phenomena.

The ground movement in the fault zone was very severe, and numerous estimates of the time duration of strong shaking range between 30 and 40 s. The first movement was vertical and was followed by a strong horizontal ground motion, which was so strong that it hindered people from getting out of bed, and in many instances people were thrown down or were unable to walk. In many areas of the country, a second intense horizontal motion was reported nearly a minute after the main disturbance. In one particular case illustrating the last report, a man tried to get out of bed and failed. He waited several seconds and tried again, failing for the second time. He stayed in bed for about 30 s, and then he was able to get up, pick up a child from a crib, and go out. As he was going out, he felt the second severe horizontal ground motion, which collapsed his house.

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CASUALTIES AND DAMAGE

The statistics for casualties and damage are given in table 8 by Departments and in table 9 by municipalities. These figures were provided by the Comite Nacional de Emergencia, Presidencia de la Republica de Guatemala. The total number of houses destroyed, as of February 15, 1976, was 254,750, and 1.07 million people were left homeless. From a total population of 3,213,962, there were 22,868 deaths and 77,190 injuries as of March 3, 1976. The total loss in Guatemala is $1,100 million (from Ministry of Finance statistics).

INTENSITY DISTRIBUTION IN GUATEMALA

The areas of maximum Modified Mercalli intensity are concentrated in and near the town of Gualán, Department of Zacapa, and to the west in the town of Mixco, Department of Guatemala. Maximum intensity in the meizoseismal area was IX. In the Gualán area, however, much of the damage could be classed as VIII. On the Modified Mercalli scale (Richter, 1958), large landslides, such as those that developed between Guatemala City and El Progreso and also between Guatemala City and Antigua, suggest an intensity greater than IX. Another factor that yields higher intensities is surface faulting, examples of which were observed in Gualán (see cover photograph) and along the Motagua fault. The authors visited, by car and helicopter, villages in areas of high, intermediate, and low damage and by using questionnaires gathered data (fig. 40) used to assess the Modified Mercalli intensity ratings throughout the nation.

These intensities are rated by using the abridged version of the Modified Mercalli intensity scale (Richter, 1958), with the following exceptions: landslides are not rated in this report as intensity X; rails bent greatly are not rated as intensity XI; and destroyed bridges are not rated as intensity XI.

TABLE 8.—*Casualties and damage, by Departments*

Department (state)	Population	Deaths	Injuries	Percent damage
Guatemala	1,681,736	3,370	16,549	68.82
El Progreso	78,364	2,028	7,767	90.43
Sacatepéquez	105,210	1,582	8,855	71.00
Chimaltenango	214,290	13,754	32,392	88.00
Santa Rosa	20,591	40	291	1.60
Solola	30,707	110	300	10.00
Totonicapán	162,678	27	89	34.00
Quezaltenango	79,241	14	228	1.00
Huehuetenango	34,362	10	50	N.A.[1]
Quiché	150,073	843	5,722	73.00
Baja Verapáz	49,820	152	718	82.50
Alta Verapáz	59,664	18	953	67.50
Izabal	183,370	73	379	40.00
Zacapa	107,148	693	1,998	72.86
Chiquimula	76,603	50	378	50.00
Jalapa	88,802	91	473	31.67
Jutiapa	91,303	13	48	10.00

[1]N.A. - Information not available.

These exceptions have been made because the Modified Mercalli intensity scale is used to represent the intensity of an earthquake based on purely vibrational effects as well as on the damage sustained by structures from the earthquake. The above effects are of a secondary nature to the seismic energy release. In the area of heavy landsliding, many adobe houses sustained no damage. Landsliding implies intensity X, but undamaged adobe houses suggest much lower intensities (fig. 41). Also, numerous houses near landslides along the highways toward the Pacific were not damaged.

Rails bent greatly are not related directly to ground shaking, but this effect is related to ground movement due to faulting, as seen in Gualán (fig. 42*A*) and near El Jicaro (fig. 42*B*), or to ground compaction, as observed in Puerto Barrios (fig. 42*C*). Another factor that yields higher intensities is surface faulting, examples of which are observed in Gualán (see cover photograph) and along the Motagua fault, near Las Ovejas (fig. 42*D*).

The Agua Caliente Bridge was destroyed, and the Benque Viejo Bridge was at the verge of collapse owing to large ground displacement in those areas. The displacements sustained by the Agua Caliente Bridge were larger than those planned in the original design for the structure. The damage to these structures gives an indication of the severity of the ground deformation but does not indicate the level or the time duration of the seismic disturbance. The Benque Viejo Bridge is similar in construction to some of the highway overpasses in the San Fernando Valley of California, which collapsed as a result of the 1971 San Fernando earthquake.

The isoseismal map shown in figure 43 represents a preliminary Modified Mercalli intensity dis-

TABLE 9.—*Casualties and damage, by municipalities*

[*This consecutive number identifies the total number of municipalities in a department (as listed in table 8).]

Municipality	Population	Deaths	Injuries	% Damage
1.* Chimaltenango	20,194	600	3,000	25%
2. San Jose Poaquie	9,795	1,000	2,657	90%
3. San Martin Jilotepeque	33,066	2,920	5,000	100%
4. Zaragoza	7,317	300	1,000	100%
5. Patzicia	10,585	811	2,248	90%
6. Sta. Cruz Balanya	2,903	100	500	80%
7. Tecpan	24,181	3,023	7,000	100%
8. Patzun	18,900	309	390	85%
9. Parramos	3,237	200	900	90%
10. El Tejar	3,039	50	900	85%
11. San Andres Itzapa	8,447	150	728	90%
12. Yepocapa	10,457	87	289	90%
13. Comalapa	18,163	3,050	5,000	95%
14. Sta. Apolonia	4,182	900	844	85%
1. Guatemala	700,504	1,195	5,550	45%
2. San Pedro Sacatequepez	10,714	720	1,667	100%
3. San Juan Sacatepequez	43,116	720	2,400	100%
4. Chuarrando	6,985	42	1,789	60%
5. Sn. Raymundo	9,225	118	1,543	60%
6. San Pedro Ayampuc	10,481	54	316	90%
7. Mixco	129,878	346	2,400	80%
8. Amatitlan	26,412	16	80	20%
9. Palencia	18,982	68	157	85%
10. Villa Canales	31,774	2	100	20%
11. Sn. Miguel Petapa	8,078	2	140	70%
12. Sta. Catarina Pinula	12,934	9	70	75%
13. Chinautla	32,763	50	15	80%
1. Progreso Cabecera	11,048	1,300	3,500	95%
2. El Jicaro	6,197	372	2,538	100%
3. San Agustin Acasagustlan	17,344	126	917	50%
4. Morazan	7,080	134	570	100%
5. Sanarate	15,253	69	137	70%

tribution of the main event in Guatemala. The isoseismal for an intensity rating VII follows the general trend of the mapped Motagua fault. The isoseismal VIII, and higher, in the Departments of Sacatépequez, Chimaltenango, Guatemala, and the southern part of Quiché, follows the general trend of maximum adobe-damaged areas.

The high intensities attenuate faster in the eastern part of the country near Los Amates. However, as one progresses west, from El Jicaro to near Sanarate, the intensities increase in a narrow area, and then, outside Sanarate, there is a sudden intensity decrease for the next 35 km and again a rather large increase to Modified Mercalli intensities of VIII and IX in the Mixco area. Guatemala City, as it appears on this map, has been assigned an *average* intensity of VII and, in the northern part of the city, an intensity rating of VIII. A detailed mapping of the intensity distribution in Guatemala City associated with the February 4 earthquake is now being done and will be presented in a subsequent separate report.

A study of intensity distributions unexpectedly showed that a number of small villages near the causative fault sustained no damage. The intensity ratings attenuate rather rapidly in a north-south direction in the eastern part of the country.

The epicenter was located west of the town of Los Amates, approximately 12 km away. The highest intensities were in Gualán and 145 km due west in Mixco. In Guatemala City, the intensity was IX in the center of the city. To the northwest of the city, the intensity was VIII along the strike of some faults mapped after the earthquake.

The intensity VII isoseismal has an east-west trend, from Los Amates, parallel to the Motagua

TABLE 9.—*Casualties and damage, by municipalities*—Continued

Municipality	Population	Deaths	Injuries	% Damage
1. Sacatepequez	26,945	277	1,251	25%
2. Sumpanjo	10,232	315	1,300	100%
3. Magdalena Milpas Altas	2,921	135	584	50%
4. Jocotenango	3,426	118	582	50%
5. San Lucas Sacatepequez	4,344	157	1,170	40%
6. San Antonio Aguas Calientes	3,866	113	544	50%
7. Pastores	4,592	127	567	30%
8. Sta. Domingo Xenaxoj	2,759	57	560	70%
9. Sn. Miguel Duenas	4,215	7	524	30%
10. Santiago Sacatepequez	7,943	218	1,247	40%
11. San Maria de Jesus	7,144	2	218	20%
12. San Bartolome Milpas Altas	1,513	27	246	40%
1. Quiche	35,147	56	175	
2. Joyabaj	32,134	600	5,497	95%
3. Chinique	4,353	35		
4. Chichicastenango	45,733	140		
1. Jutiapa	54,680		18	
2. Asuncion Mita	29,071	13	30	
1. Zacapa	34,703	198	475	50%
2. Gualan	23,375	187	550	99%
3. Rio Hondo	9,637	95	281	80%
4. Cabañas	5,817	89	240	95%
5. Huite	3,941	67	152	75%
6. Usumatlan	3,771	26	150	50%
7. Teculutan	5,933	31	150	60%
1. Baja Verapaz	21,913	119	377	75%
2. Rabinal	20,393	33	341	90%
1. Izabal	38,903	30	167	50%
2. Los Amates	45,537	14	158	2%
3. Morales	52,677	29	54	
1. Totonicapan	52,688		10	50%
2. St. Maria Chiquimula	15,161	3	10	
3. Momostenango	43,398	3	11	
4. San Cristobal Totonicapan	16,623		3	
5. San Fco. el Alto	19,329	21	55	50%
1. Chiquimula	38,872	10	110	
2. Esquipulos	19,304	20	110	1%
3. Sn. Jacinto	3,851	20	158	

fault for a distance of 150 km to near San Antonio La Paz in the Department of El Progreso. From San Antonio to Zaculeu in the Department of Quiché, an east-west distance of another 85 km, the intensity VII isoseismal broadens considerably to 72 km in width. The intensity VIII and IX isoseismals follow a trend parallel to the trend of surface faulting. The dashed line is questionable for the intensity VIII isoseismal continuation to the west between Sanarate and to the east of Guatemala City. The number of landslides in this area was very high, on the average one landslide per kilometre. From Guatemala City toward El Progreso, there were 32 landslide areas as far as Kilometre 29 near the town of El Chato and a total of 54 landslide zones in the first 48 km on this main highway toward the Atlantic Ocean. A landslide zone consists of one to three large landslides obstructing the highway.

On this road there were two bridges that suffered considerable damage. The Agua Caliente Bridge collapsed and impeded traffic, and the Benque Viejo Bridge was on the verge of collapse (Husid and others, this report). Severe landslides occurred also

TABLE 9.—*Casualties and damage, by municipalities*—Continued

Municipality	Population	Deaths	Injuries	% Damage
1. Solola	25,819	110	300	
1. Jalapa	45,425	27	254	50%
2. San Pedro Pinula	23,846	9	97	25%
3. Mataquescuinla	16,145	55	122	20%
1. Sta. Rosa	14,127	40	291	
1. Alta Verapaz	43,505	15	700	60%
2. Sta. Cruz Verapaz	3,508	3	253	70%
1. Quezaltenango	65,526	14	228	
1. Aguacatanan	18,492			
2. San Sebastian Huehuetenango	7,824			
3. San Pedro Necto	11,371			
4. San Miguel Acatan	15,011			
5. Concepcion	8,102			
6. Newton	12,613			
7. St. Ana Huista	4,755			
8. La Libertad	14,756			
9. Colotenango	9,458			
10. San Gaspar Ixchil	3,058			
1. Villa Nueva (Guate)		5	12	8%
2. Acatenango (Chimaltenango)		22		
Total		22,525	74,027	

along the main highway to the Pacific Ocean, between Guatemala City and Antigua. Landsliding interrupted road traffic along these two main throughways and also disrupted railroads near Las Ovejas, Gualán, El Progreso, Río Hondo, and Puerto Barrios.

The preliminary intensity distribution in Guatemala (fig. 43) suggests that the shaking intensity was greater in the western part of the country. This isoseismal pattern suggests a fault propagation rupture from east to west. The isoseismals broaden to the west, a phenomenon similar to a Doppler effect, which creates a constructive interference pattern to the west. Several small villages were located near and at intermediate distances from the causative fault; for example, adobe construction in Jones, about 8 km from the fault, sustained no damage. Also, in several communities south of the Motagua fault, such as San Pedro Pinula nearly 25 km from the fault, adobe construction sustained no damage. Numerous small villages in which adobe buildings sustained no damage were observed 8 to 30 km from the causative fault. Other towns, such as Entre Rios approximately 37 km due east of Morales, near the extension of the Motagua fault, had an intensity rating of only V.

The pattern of isoseismals displayed in figure 43 may be the effect of a moving source in the near field. This effect is shown schematically in figure 44 (Benioff, 1955) to be the progression of a discrete number of points. The initiation of the fault motion is near Los Amates, at point 0, and terminates at point 8, toward Guatemala City. The largest circle represents a wavelet at point 0, which in the time domain is shown at the lower part of this diagram and is identified with a 0, and the succesive circles represent the wavelet position as it propagates from points 1, 2, 3. . ., and so on. There is a time delay between these points, as is seen in the two lower diagrams. The lower left diagram represents the signal from each point as seen at a station west of the fault, and the lower right diagram represents the signal as seen at a station east of the fault. The composite signal for each direction of propagation is shown as the resultant in the lower part of figure 44. The energy can be measured as the square of the velocity amplitude; hence, the resultant wavelet traveling to the west, shown at the

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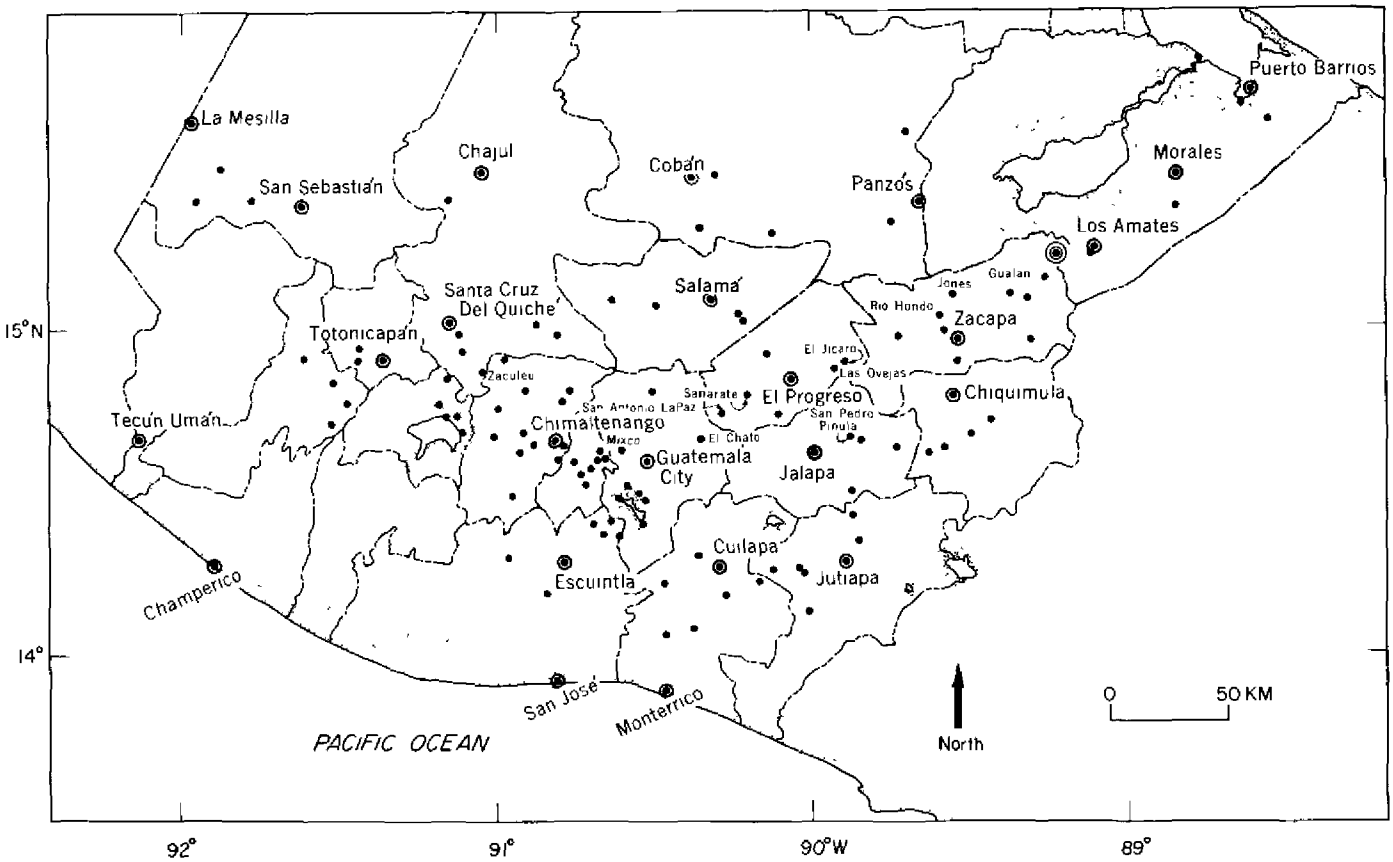

FIGURE 40.—Intensity sampling distribution. Each dot represents the location where one or more questionnaires was completed during a survey taken in Guatemala. Largest circle indicates epicenter location of main event. (Base map modified from Guatemala Instituto Geográfico Nacional, 1974, 1:500,000.)

lower left in figure 44, has a larger concentration of energy than the slightly dispersed wavelet traveling in the opposite direction.

The possibility of a fault rupture traveling from east to west (suggested in fig. 43) could be verified with teleseismic data at western azimuths. Also, the suggestion of a double rupture or a multiple earthquake from the isoseismal distribution is plausible. If this second alternative is adopted, the first earthquake will be constrained to the observed surface faulting from Los Amates to Kilometre 15 southwest of El Progreso. The second event could be associated with the secondary faulting observed in the Mixco area.

Other factors that may enter into the intensity distribution pattern shown in figure 43 are seismic-wave amplification effects, topographic seismic-wave amplification, influence of the surficial soil conditions, and depth of the water table.

The high-level isoseismals VI, VII, and VIII represent the shape of the radiation pattern in the near field, assuming the rupture started near the epicentral region and propagated west. A similar suggestion made by Hanks (1975) correlates the intensity VI and VII isoseismals from the San Fernando earthquake with the radiation pattern for 8-s Rayleigh waves and also with the azimuthal variations of the amplitude ground displacements.

The isoseismal map was plotted on a 1:500,000 geologic map of Guatemala (edition by Bonis, Bohnenberger, and Dengo, 1970), and no simple correlation was found between the gross surficial geology and the intensity distribution. There is a correlation between the fault that slipped during the February 4 earthquake and the intensity distribution. West of Guatemala City is the Mixco fault, which has a north-south trend. In this region, the intensity rating attains a maximum of IX.

The earthquake was felt by nearly everyone over an area of at least 93,125 km^2, suggesting that an intensity V or higher extended over that area. The areas felt for intensities VI and higher are given in table 10.