

CATALOG OF HISTORIC SEISMICITY IN THE VICINITY OF THE
CHIXOY-POLOCHIC AND MOTAGUA FAULTS, GUATEMALA

Randall A. White
U. S. Geological Survey
Office of Earthquakes,
Volcanoes and Engineering
Branch of Seismology
345 Middlefield Road, MS 77
Menlo Park, CA 94025

FINAL REPORT

for

El Instituto Nacional de
Sismologia, Vulcanologia,
Meteorologia, e Hidrologia
Guatemala City, Guatemala

Open-File Report 84-88

This report is preliminary and has not been reviewed for conformity with
U. S. Geological Survey editorial standards and stratigraphic nomenclature.

CATALOG OF HISTORIC SEISMICITY IN THE VICINITY OF THE
CHIXOY-POLOCHIC AND MOTAGUA FAULTS, GUATEMALA

ABSTRACT

A new catalog of shallow historical earthquakes for the region of the Caribbean - North American plate boundary in Guatemala is presented. The catalog is drawn mostly from original official documents that are considered to be primary accounts. It contains 25 damaging earthquakes, 18 of which have not previously been published. The catalog is estimated to be complete for magnitude 6.5 earthquakes since 1700 for most of the study area. The earthquakes in this catalog can be grouped into periods of seismic activity alternating with extended periods of seismic quiescence as follows:

1538		large damaging earthquake
1560 (1539?) - 1702	1st quiet period	no known damaging earthquakes
1702 - 1822	1st active period	18 damaging earthquakes
1822 - 1945	2nd quiet period	no damaging earthquakes
1945 - 1983	2nd active period	6 damaging earthquakes

The first active period terminated with the two part rupture of the eastern portion (M 7.3 to 7.5) of the Chixoy-Polochic fault in 1785 and the western portion (M 7.5 to 7.7) in 1816, followed by 5 years of regional aftershocks. The second active period has probably culminated with the 1976 (Mw 7.5) rupture of the Motagua fault. The following 6 years have seen 3 damaging earthquakes that may be regional aftershocks, and, if so, may be terminating a comparatively abbreviated active stage. It is estimated that slip from earthquakes in this catalog would accommodate historic slip rates of 1.0 ± 0.5 cm/yr and 0.5 ± 0.3 cm/yr for the Chixoy-Polochic and Motagua faults respectively, in good agreement with the geologically determined holocene slip rates.

The periods of seismic activity appear to be terminated by the major rupture of either the Chixoy-Polochic or Motagua faults, the two principal sub-parallel faults that form the transform plate boundary in Guatemala. Although the plate boundary is not simple in this region, the alternating nature of the regional seismic activity with seismic quiescence is a classic example of the seismic cycle concept. It is estimated that a very large earthquake (M 7.5) may recur along a transform boundary fault between 160 to 300 years after the previous such earthquake in the region.

INTRODUCTION

On February 4, 1976 a Mw 7.5 earthquake ruptured about 240 km of the Motagua fault in Guatemala (Plafker, 1976) killing over 23,000 people. Recently it was discovered that a similar size earthquake (M 7.5 to 7.7) ruptured the western portion of the adjacent Chixoy-Polochic fault on August 22, 1816 (White, 1984). These represent only the latest in a long sequence of very large earthquakes along these two strike-slip faults, which taken together form the Caribbean - North American plate boundary in this region (see Figure 1, inset). It is the purpose of this paper to put the long-term behavior of the transform fault region of Guatemala into better historical perspective.

DATA SOURCES

Several works have been published that describe damage in Guatemala from earthquakes dating from 1526 (see for example, Montessus de Ballore, 1888; Sapper, 1925; Diaz, 1930; or Vassaux, 1969). Grases (1974) has compiled most of this published information. These works however, consist mainly of lists of dates, draw on few primary sources, and at most give only details for the largest cities. As such they are too incomplete and unreliable for estimating epicentral locations and intensities.

An archival search was conducted for primary accounts of historical earthquakes in Guatemala at the Archivo General de Central America (Guatemala City), the Archivo Eclesiastico de Guatemala (Guatemala City), and the Archivo General de las Indias (Seville, Spain). From more than 1000 handwritten colonial documents inspected, 90 documents were found which contain data on shallow back-arc (i.e. non-volcanic and non-subduction zone) earthquakes. Of these, 40 documents pertain to the just largest earthquake, that of 1816 (Mw 7.5 to 7.7), and these data are presented elsewhere (White, 1984). The appendix to this report contains quotes and occasional abstracts from the remaining 50 documents and are listed by the date of the earthquake. Also given is the town affected, the date the manuscript was written, and the archival document reference number. With the exception of two documents, all of the documents from before 1860 are official communications between various functionaries of colonial Guatemala, mostly petitions from local priests or mayors asking for reconstruction funds or tax relief. After this date, the data come from publications of the Observatorio Nacional founded about 1860, and from local newspapers.

ESTIMATION OF MAGNITUDES

Light to moderate damage to a church is estimated to be equivalent to Modified Mercalli (MM) intensity VII while partial collapse is equivalent to MM intensity VIII. Many of the old documents, however, do not give sufficient detail to distinguish the various levels of intensity. For this reason the area of damage is taken to coincide with the area of MM intensity VII and greater. Magnitudes for large earthquakes prior to this century have been estimated using the maximum dimension of the area

of Modified Mercalli intensity VII damage (see White, 1984, figure 5). For smaller events for which significant damage is reported at just a single site, the magnitude is estimated to be between 5.5 and 6.5. This is based on distribution of intensities for recent instrumentally recorded Guatemalan earthquakes of 1945 (M_L 5.5), 1959 (M_s 6.5), 1980 (M_s 6.4), and 1982 (m_b 5.5). It is possible that an earthquake as small as magnitude 5.0 might generate intensity VII damage at a single site if the epicenter is located within a very few kilometers of the site as happened at Tecpan in 1978.

HISTORICAL EARTHQUAKES OF CENTRAL GUATEMALA

Table 1 lists in chronological order historical earthquakes of central Guatemala whose epicenters were judged to be more than 10 km northeast of the quaternary volcanic chain and west of Puerto Barrios. The table also gives the province affected, the estimated magnitude, and a brief summary of the reported damage to particular towns. Figure 1 shows the locations of place names described in both Table 1 and the Appendix. Figure 2 shows the mapped faults and damage areas of the smaller earthquakes. Figure 3 shows the areas of known damage for the largest earthquakes, those of 1538, 1785, 1816 and 1976, and Figure 4 shows the corresponding probable fault ruptures for these events.

An Early Historic Earthquake

An earthquake occurred in 1538 near the town of San Pedro Carcha. Because the report of damage comes from a single site the magnitude is difficult to estimate. Nevertheless, the earthquake was probably large because it caused extensive landsliding and so frightened a village of indigenous people that the entire village emigrated. Only the large earthquakes of 1765, 1816 and 1976 are known to have caused such landslides and to have driven indigenous people to emigrate on such a scale. It could have resulted from a major rupture of the Chixoy-Polochic fault similar to that of 1785. This region was virtually unpopulated by the Spanish until 1560.

The First Quiescent Period: 1560 (1539?) - 1702

Several lines of evidence, each rather weak when considered alone, suggest that the period from 1538 (or at least from 1560) through 1702 was quiescent for most of the region:

- 1) By 1560 the Dominican Order of the Roman Catholic Church had established churches in Verapaz province at Coban, San Cristobal, Salama and Cubulco. A priest, Fr. Francisco Montero de Miranda, who reported the 1538 earthquake, prepared a description of the province for the King of Spain in 1577 (Montero de Miranda, 1577). In it he states that "notable earthquakes...don't occur in this region, and those [earthquakes] that do occur, don't cause any alarm." This statement is important because it demonstrates that the major earthquakes of 1565 and 1566, and 1575, which caused damage in western Guatemala and Chiapas, were undoubtedly generated coastward at the subduction zone, not in the back-arc region.

- 2) Another priest, Francisco de Viana, who resided in San Cristobal Verapaz from 1556 to 1608 mentions only the small earthquake associated with the cave collapse in 1590 for this 52 year span (Ximenez, 1719).
 - 3) For the 13 towns of the provinces of Zacapa and El Progreso, which were all very badly damaged in the 1976 earthquake, no references to any earthquakes were found in 48 surviving manuscripts from the 16th century, nor in 104 manuscripts from the 17th century (Feldman, 1982).
- The distribution of the Spanish Population, and therefore the possible reporting sources, is very sparse prior to 1700, especially in the Huehuetenango area, but the overall total lack of earthquake reports indicate that no large earthquakes occurred between 1560 and 1700, and that if smaller damaging earthquakes occurred at all, they were uncommon.

The first Active Period: 1702 - 1822

Damaging earthquakes became somewhat common after the beginning of the 18th century. Damage is reported from moderate-sized (M 5 to 7) earthquakes in 1702 or 1703, 1713, 1714, 1728, 1733, 1741, 1743, 1750, 1765, 1786, 1795, 1798, 1817, 1820, and 1821. These earthquakes are shown on Figure 2. The 1733 and 1765 earthquakes both caused damage throughout most of Chiquimula province. In 1733 the higher intensities seem to have occurred from Jocotan to Quezaltepeque, but in 1765 were centered around the town of Chiquimula. The magnitudes of both earthquakes have been crudely estimated from the area of damage to churches (MM intensity VII) to be about 6.7 to 7.2. Whether these earthquakes occurred on the strike-slip Jocotan-Chamelecon fault or along north-south normal faults in the area is unknown.

Damage reports from the earthquake of 1785 indicate MM intensity VIII at sites from western Baja Verapaz to the east end of Lake Izabal 175 km away and bracket the eastern half of the Chixoy-Polochic fault (see Figure 3). The eastern terminus of rupture must have been between Castle San Felipe and Omoa, since Puerto Cortez or Omoa would certainly have reported the event had it caused damage in that area. It is assumed that the western terminus of rupture in 1785 approximately abuts that of 1816 at about San Cristobal Verapaz since the areas of damage for the two earthquakes overlap there. Using a figure of 175 to 220 km as an estimate of the maximum dimension of the area of damage, the magnitude of the 1785 earthquake is estimated to be 7.3 to 7.5.

The largest earthquake in the historic record of back-arc Guatemala is that of 1816. It apparently ruptured the Chixoy-Polochic fault from about San Cristobal Verapaz westward. Damage occurred as far west as San Cristobal Las Casas, in central Chiapas, Mexico (see Figure 3 for location), but unfortunately no other data has been found for this sparsely settled region of Mexico. The main shock caused intensity MM VII damage at San Cristobal las Casas and an aftershock not reported in Guatemala caused additional damage there. It is not known if this damage resulted from rupture of the Mexican portion of the Chixoy-Polochic fault, or whether sympathetic faulting on secondary reverse faults to the northwest may have been responsible (see Figure 4 where queried). From the fault map it can be seen that the length of fault available to

rupture in 1816 must have been about 240 kms, equivalent to that of the Motagua fault in 1976 (Mw 7.5). The area of MM intensity VII damage in 1816, however, is considerably broader than that of 1976, and suggests a greater magnitude of about 7.5 to 7.7 for the earthquake of 1816. This could have resulted if greater slip (3 to 5 meters) was involved in 1816 compared to that in 1976 (1.4 to 3.4 meters). (For more details on the 1816 earthquake, see White, 1984)

The second Quiescent Period: 1822 - 1945

During the 18th century, the evidence for the complete absence of damaging earthquakes after 1821 is very good. By 1840 the Jesuits were operating an observatory and reporting felt events (generated primarily at the volcanic chain or subduction zone), and newspapers began to publish regularly. By 1854 the Guatemalan government began an observatory, and began reporting felt events. From 1854 through 1870 for example, 177 earthquakes were reported for Guatemala as a whole (Montessus de Ballore, 1888), but not a single felt event was reported for the back-arc area. Later, events were reportedly felt weakly in Coban in June, 1881, in Chinique on August 13, 1881 and in Salama on March 2, 1882, and strongly around Quiche province on January 20, 1930. In 1926 a 3-component Weichert's seismograph was installed in a vault at the observatory in Guatemala City and began continuous recording. These seismograms were scanned for any evidence of shallow earthquakes in the study region. From 1926 to 1945 evidence for only one significant event was found, that of January 20, 1930 whose magnitude is estimated from the seismogram to be M_L 4 to 5. Thus, except for the possible exception of the region to the north of the Chixoy-Polochic fault, much of which is still very sparsely populated, felt events were very uncommon, and it is unlikely that any damaging earthquake (i.e. $M > 6$) occurred between 1821 and 1945.

Comments on the second Active Period: 1945 - 1983?

The damaging earthquakes of the second active period begin with the Quirigua earthquake of August 10, 1945, undoubtedly produced by movement on the Motagua fault. A magnitude of M_L 5.5 has been estimated from the seismogram generated by the Weichert's seismograph in Guatemala City. A M_s 6.4 earthquake occurred on February 20, 1959, and Ivan Wong and David Schwartz of Woodward-Clyde Associates (1979, and oral communication) report that it caused extensive damage to plantations near the Quiche - Alta Verapaz border area.

The Motagua Valley earthquake of February 4, 1976 caused over 22,000 deaths in Guatemala and is by far the largest natural disaster ever to befall the country. A moment magnitude, Mw, of 7.5 and a moment of 2.6×10^{27} have been determined by the U. S. Geological Survey (see Espinosa, 1976). Plafker determined that slip on the Motagua fault ranged from 1.0 to 3.4 meters and averaged about 1.4 meters over the 240 of observed surface rupture. This earthquake may have been the cycle-controlling rupture that will terminate a rather abbreviated active period, at least in eastern Guatemala. Evidence for regional relaxation comes from the typical exponential decay of regional aftershocks with time that has been

observed in data gathered by the Guatemala national network operated by the Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia (INSIVUMEH). If the 1976 event were but a prelude to a larger cycle-controlling rupture, it is thought that there would have been anomalously higher numbers of aftershocks or the rate would decay more slowly. The subsequent damaging earthquakes in Tecpan, 1978, mb 5.0, and Puerto Barrios, 1980, Ms 6.5, occurred at the two ends of the aftershock zone of the 1976 earthquake, while the Chamagua earthquake of 1982, Ms 5.5 occurred well off the center of the rupture area. These events occurred at exactly those locations predicted from regional postseismic strain relaxation (Stein, 1983).

COMPATIBILITY OF HISTORIC AND GEOLOGIC SLIP RATES

The historic record shows that the last major rupture of the Motagua fault prior to 1976 probably occurred before 1560. From bulk soil samples taken from a trench across the Motagua fault, Schwartz (oral communication) found evidence for another event that must have occurred after about 1300, so the most recent inter event interval was 416 to 676 years. For the 1976 earthquake the surface displacement was found to be 1.4 meters average and 3.4 meters maximum (Plafker, 1976). If all slip is considered to be seismic and if the slip in 1976 is taken to be typical for large earthquakes on this fault, this gives a slip rate of about 0.5 ± 0.3 cm/yr for the last several hundred years. This is comparable to the holocene rate of 0.6 cm/yr determined by Schwartz (1979) from progressively offset stream terraces.

For the Chixoy-Polochic fault a rough estimate of the historical rate of displacement can be made if the 1538 earthquake is assumed to be part of an earlier active stage that terminated at about that date or at least before 1560. If the displacement per event is taken to be 1.4 to 3.4 meters as for the Motagua fault in 1976, and the inter event interval was 225 to 247 years, this gives an historic rate of 1.0 ± 0.5 cm/yr.

If these two slip rates are summed, the historic rate of displacement along this portion of the Caribbean - North American plate boundary is about 1.5 ± 0.8 cm/yr. This compares very well with the geologic rate which has been estimated by Schwartz (1979) to be "between 0.45 and 1.8 cm/yr but probably closer to the higher rate." This rate is only about 40% of the long-term far-field rate of 3.7 cm/yr estimated by Sykes and McCann (1982). It is interesting to note that in the San Francisco peninsula region of northern California where the San Andreas fault is also splayed into several sub-parallel subsidiary faults, slip on the San Andreas fault alone similarly accounts for about 40% of the long-term far-field plate rate (Ellsworth and others, 1981).

CONCLUSIONS FROM HISTORICAL SEISMICITY OF CENTRAL GUATEMALA

1. There is evidence for an extended period of quiescence (1560 or earlier to 1702) preceded by a large earthquake in 1538.
2. A remarkable period of 118 years (1703 to 1821) of seismic activity occurred during which time there occurred 16 damaging earthquakes.
3. During this active period most of the earthquakes occurred not on the Chixoy-Polochic fault but on adjacent faults throughout the highlands up to 80 km distant.
4. This active period appears to have been modulated by the rupture of the Chixoy-Polochic fault (1785, 1816), and terminated in 1821 after 5 years of regional aftershocks.
5. A quiescent period of 123 years passed from 1822 to 1945 during which a few felt events were reported but not a single damaging event occurred.
6. Recently, activity began in 1945 and may have ended, at least in western Guatemala, with the 1976 Motagua fault rupture and associated aftershocks at Tecpan, 1978 (mb 5.0), Puerto Barrios, 1980 (Ms 6.4), and Chanmagua, 1982 (mb 5.5).
7. The two quiescent stages, from 1560, or slightly earlier, to 1702, and from 1822 to 1945, were of approximately equal duration, while the duration of the two active stages, from 1702 to 1821 and from 1945 to 1982, differ by more than an order of three. See Figure 4 for a time history of the damaging earthquakes.
8. The historic slip rates are found to be 1.0 ± 0.5 and 0.5 ± 0.3 cm/yr for the Chixoy-Polochic and Motagua faults respectively, in good agreement with the geologically determined slip rates.

TABLE 1. CATALOG OF HISTORIC EARTHQUAKES OF CENTRAL GUATEMALA

1538	Alta Verapaz	M 6.5 to 7.5
A violent earthquake caused a large landslide about 3 km east of present day San Juan Chamelco caused landslides, and so frightened the inhabitants of the area that they migrated about 50 km to the east.		
1590	Alta Verapaz	M 3 to 5
At San Cristobal Verapaz, a small earthquake reportedly "caused" a large hole in the ground that now contains a small lake. No damage reported to the nearby church. Undoubtedly this event was a cave collapse in this karst region.		
1702 or 1703	Baja Verapaz	M 5.5 to 6.5
A destructive earthquake totally ruined the main chapel of the church of Cubulco.		
1713 August 12	Quiche	M 5.5 to 6.5
An earthquake destroyed the church of Zacualpa.		
1714 May 5	eastern Chiapas (Mexico)	M 5.5 to 6.5
An earthquake damaged the walls and roof of the church in Amatenango.		
1728	Alta Verapaz	M 5.5 to 6.5
An earthquake damaged the town of Dolores Manche and the church in Tactic.		
1733	Chiquimula	M 6.7 to 7.2
Sometime before July during 1733, large earthquakes collapsed the churches of Quetzaltepeque and Jocotan. The churches of Chiquimula, Santa Clara, San Luis Jilotepeque, Ipala, and Santa Catarina Mita were badly damaged.		
1741 February 15	Alta and Baja Verapaz	M 6.5 to 7
Earthquakes badly damaged the churches of Coban and Cubulco and probably Tamaju.		
1743 October 15	Chiquimula	M 6 to 6.5
An earthquake caused some damage to the churches in Zacapa and Chiquimula.		
1750 March 8	Huehuetenango	M 6.3 to 6.7
An earthquake caused the collapse of the church in Soloma and is almost certainly the same earthquake that ruined the church at Chiantla.		

- 1765 June 2 Chiquimula M 6.7 to 7.2
A major earthquake damaged most of Chiquimula province and the town of Zacapa. Twenty four people were killed in Chiquimula itself and most of the rest of the inhabitants were injured. Many landslides occurred (in both in the mountains and on the plains) and new hot springs gushed out, burning the crops. Aftershocks were continuous for two months and sporadic aftershocks were felt through December. Slight damage occurred in Jalapa and the valley of Santa Rosa, and rang bells in Antigua.
- 1785 Jan 6 Alta, Baja Ver., Isabal M 7.3 to 7.5
A major earthquake badly damaged the churches of Verapaz. Churches were also damaged in Coban, Rabinal, and Tactic. At the Castle San Felipe most of the walls collapsed. Slight damage reported from Cucuyaga, Honduras. Antigua was apparently not affected.
- 1786 southern Quiche M 5.5 to 6.5
An earthquake damaged the church in Chichicastenango and probably is the same earthquake that destroyed the church at Chinique at about this same time.
- 1795 Nov. or Dec. Huehuetenango M 5.5 to 6.5
Earthquakes damaged the church in Chiantla and also in Huehuetenango where some of the walls subsequently collapsed.
- 1798 July 2 Alta Verapaz M 5.5 to 6.5
An earthquake ruined the church in Lanquin on this date.
- 1804 Chiapas (Mexico) M 5.5 to 6.5
An earthquake damaged the cathedral in San Cristobal las Casas somewhat, requiring the rebuilding of part of the roof. (This event may not have been of shallow origin.)
- 1816 July 22 Verapaz to Chiapas M 7.5 to 7.7
A very large earthquake struck just after midnight. Every building in at least six towns around Soloma collapsed, including 9 churches and convents. At least 23 people perished and 57 landslides occurred in this region. Lesser damage occurred from western Verapaz province to San Cristobal las Casas (Mexico) and as far south as Santa Lucia Utatlan, near Solola. The earthquake was preceded by about 3 hours by a strong foreshock. Aftershocks were still being felt in the epicentral area at the rate of over 40 per day more than a month later.
- 1817 January 30 Chiapas (Mexico) M 5.5 to 6.2
An apparent aftershock of the above earthquake caused further damage to the cathedral at San Cristobal las Casas.
- 1820 June 6 Baja Verapaz M 5.5 to 6.5
Earthquakes ruined the church at Salama on this date.

- 1821 May 6 Quiche M 5.5 to 6.5
A locally strong earthquake destroyed the church and conventual house in San Pedro Jocopilas and the church in San Antonio Ilotenango, but apparently caused no significant damage in the provincial capital of Totonicapan, about 20 km to the southeast.
- 1881 June Alta Verapaz M 3.5 to 5
An earthquake was felt in Coban.
- 1881 August 13 Quiche M 3.5 to 5
An earthquake was felt in Chinique.
- 1882 March 2 Baja Verapaz M 3.5 to 5
Five earthquakes were felt in Salama on this date but apparently caused no damage.
- 1930 January 20 northern Quiche M 4 to 5
A strong earthquake was reportedly felt in Alta and Baja Verapaz and Huehuetenango departments. No damage was reported and judging from the small amplitude generated on the Weichert's seismograph in Guatemala City, must have been less than magnitude (M_L) 5.0.
- 1945 August 10 Isabal M_L 5.5
An earthquake damaged the hospital and cracked one of the Mayan stellas in Quirigua near Los Amates.
- 1959 February 20 A. Verapaz, Quiche 6.5
An earthquake badly damaged ranches in northern Quiche department.
- 1976 February 4 Motagua Valley Mw 7.5
An earthquake ruptured the Motagua fault for at least 240 km, killing over 23,000 people and destroying villages in the departments of Zacapa, El Progreso, Guatemala, Sacatepequez, Isabal, and Baja Verapaz (see U. S. Geol. Survey Prof. Report 1006).
- 1978 July 29 Chimaltenango mb 5.0
5 people killed and 12 missing in Tecpan.
- 1980 August 9 Izabal Ms 6.4
2 people killed and many injured in Puerto Barrios. Damage occurred there and in Livingston and also in northwestern Honduras. Other damaging earthquakes have occurred in this area, considered to be somewhat outside the area of this study, in 1773, 1809, 1856, 1913.
- 1982 September 29 eastern Chiquimula mb 5.5
3 killed, several injured. About 50 houses destroyed and 500 damaged around Chamagua, about 15 km east of Esquipulas, where a 10 cm high and several km long scarp was observed. Many more houses were damaged in the adjacent Merendon-Ocotepeque area of Honduras.

ACKNOWLEDGEMENTS

I thank W. E. Ellsworth and J. Dieterich for suggestions for the improvement of this manuscript.

I gratefully acknowledge the support and encouragement of Ing. Estuardo Velasquez Vasquez and Ing. Eddy Sanchez Bennett of the Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia (INSIVUMEH), Guatemala, and David H. Harlow of the U. S. Geological Survey. I owe special thanks to Lic. Manuel Rubio Sanchez, Dr. Italo Morales Hidalgo, Dr. Lawrence Feldman, and Lic. Agustin Estrada Monroy who sifted through 1000 plus handwritten documents.

This work has been supported by U. S. Geological Survey contracts 3-9930-01163 and 4-9960-51101 as part of the Earthquake Prediction Program. The work was partially funded by the Agency for International Development, Office of Science and Technology as part of the Guatemalan Earthquake Hazards Assessment Program, a cooperative project between the U. S. Geological Survey and INSIVUMEH, Ministerio de Comunicaciones, Caminos y Obras Publicas, Government of Guatemala.

- Diaz, V. M. (1930). *Comociones Terrestres en la America Central, 1549 - 1930*, Tipografia El Santuario, 268 pp.
- Espinosa, A. F. (1976). *The Guatemalan Earthquake of February 4, 1976, A Preliminary Report*, U. S. Geological Survey Professional Paper 1002, 90 p.
- Feldman, Lawrence H. (1982). *Colonial Manuscripts of Chiquimula, El Progreso and Zacapa departments, Guatemala*, Museum of Anthropology, University of Missouri, 597 p.
- Grases, Jose, (1974). *Sismicidad de la Region Centroamericana Asociada a la Cadena Volcanica del Cuaternario, V. II*, Caracas, 253 p.
- INSIVUMEH, (1978). *Boletin Sismologico Año 1978*, Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia, p. 16.
- INSIVUMEH, (1980). *Boletin Sismologico Año 1980*, Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia, p. 16.
- INSIVUMEH, (1982). *Boletin Sismologico Año 1982*, Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia, p. 16.
- Montero de Miranda, Francisco (1577). *Memorias sobre la Provincia de Vera Paz*, p. 5.
- Montessus de Ballore, F. (1888). *Tremblements de Terre et Eruptions Volcaniques au Centre-Amerique*, Memoire recompense par Academic de Sciences et Societe savante de Saone-et-Loire, Dijon, 285 p.
- Muehlberger, W. R., and A. W. Ritchie (1975). *Caribbean-Americas plate boundary in Guatemala and southern Mexico as seen on Skylab IV orbital photography*, *Geology*, 86, p232.
- Plafker, George (1976). *Tectonic Aspects of the Guatemala Earthquake of 4 February 1976*, *Science*, V. 193, pp 1201-1208.
- Rockstroh, E. (1883). *Temblores y Erupciones en Centro-America*, *Revista del Observatorio central de Guatemala*, no. 1, 1883, pp 25 - 39.
- Revista del Observatorio central de Guatemala (1883 through 1940)*.
- Sapper, Carlos (1925). *Los Volcanes de la America Central: Estudios sobre America y España, extra-serie 1*, verlag. Von Max Niemeyer, Haale (saale), p. 10-20.
- Schwartz, D. P., Cluff, L. S., and T. W. Donnelly (1979). *Quaternary faulting along the Caribbean-North American Plate Boundary in Central America*, *Tectonophysics*, 52, p 441.
- Stein, R. S., and M. Lisowski (1983). *The 1979 Homestead Valley Earthquake Sequence, California: Control of Aftershocks and Postseismic Deformation*, *Journal of Geophysical Research*, 88, pp. 6477-90.
- Vassaux P., Jose (1969). *Cincuenta anos de Sismologia en Guatemala*, Ministerio de Agricultura, Direccion de Recursos Naturales Renovables, Observatorio Nacional, Guatemala, 98 p.
- White, Randall A. (1984). *The Guatemala Earthquake of 1816 on the Chixoy-Polochic Fault*, *Bulletin of the Seismological Society of America* (submitted November 1983).
- Woodward-Clyde Consultants (1979). *Microearthquake Investigation for the Chulac and Xalala Hydroelectric Projects, Final Report for Instituto Nacional de Electrificacion, Guatemala*, p 10.
- Ximenez, Fray Francisco (1719). *Historia de la Provincia de San Vincente de Chiapa y Guatemala, V. II*, Biblioteca Goathemala de la Sociedad de Geografia e Historia, VII, 1930 edition, p. 267.

FIGURE CAPTIONS

- Figure 1. LOCATION MAP OF SITES DAMAGED. Only those referred to in the text or appendix are shown. Provinces are indicated by capital letters, towns by smaller print. Heavy lines are approximate locations of mapped faults. Stars show locations of the volcanoes of the quaternary volcanic chain. Inset shows the general tectonic setting of the region.
- Figure 2. LOCATION MAP OF FAULTS AND SMALLER DAMAGING EARTHQUAKES. Heavy lines indicate mapped faults, modified from Bonis et al. (1970) and Muehlberger and Ritchie (1975). Circles are drawn to enclose towns for which damage was reported. Smallest circles enclose only a single town.
- Figure 3. DAMAGE AREAS OF LARGE BACK-ARC EARTHQUAKES. Shaded areas are areas of Modified Mercalli intensity VII or greater, i.e. the areas of damage, for the 1538, 1785, 1816, and 1976 earthquakes. The number of possible reporting sources in 1538 was extremely limited, but from the severity of the damage, may have been similar to the 1785 earthquake. Note that the stipled damage area of 1816 is not continuous. Damage was serious at San Cristobal las Casas but no other damage was reported in Mexico, again probably due to few reporting sources.
- Figure 4. PROBABLE FAULT RUPTURES OF THE LARGE BACK-ARC EARTHQUAKES. Heavy lines indicate the probable fault ruptures along the Chixoy-Polochic fault in 1785 and 1816, and the rupture of the Motogua fault in 1976. Fault is queried where rupture is rather uncertain due to lack of reporting sources in those areas.
- Figure 5. MAGNITUDE VS. TIME FOR GUATEMALA. The damaging earthquakes are shown for the back-arc area of Guatemala. Horizontal scale is time in years from 1538 to the present. Height of the bar indicates approximate magnitude.

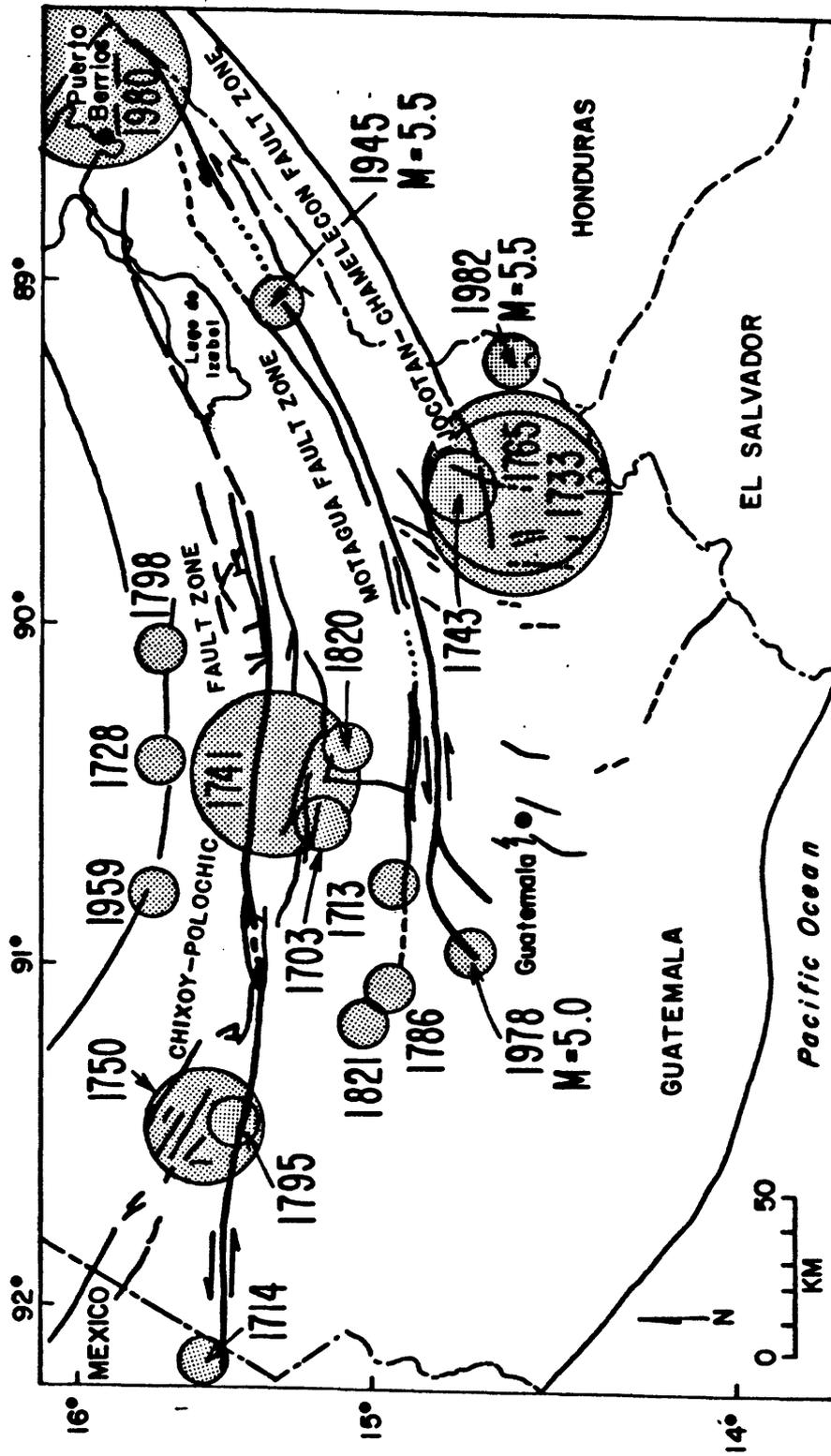


FIGURE 2

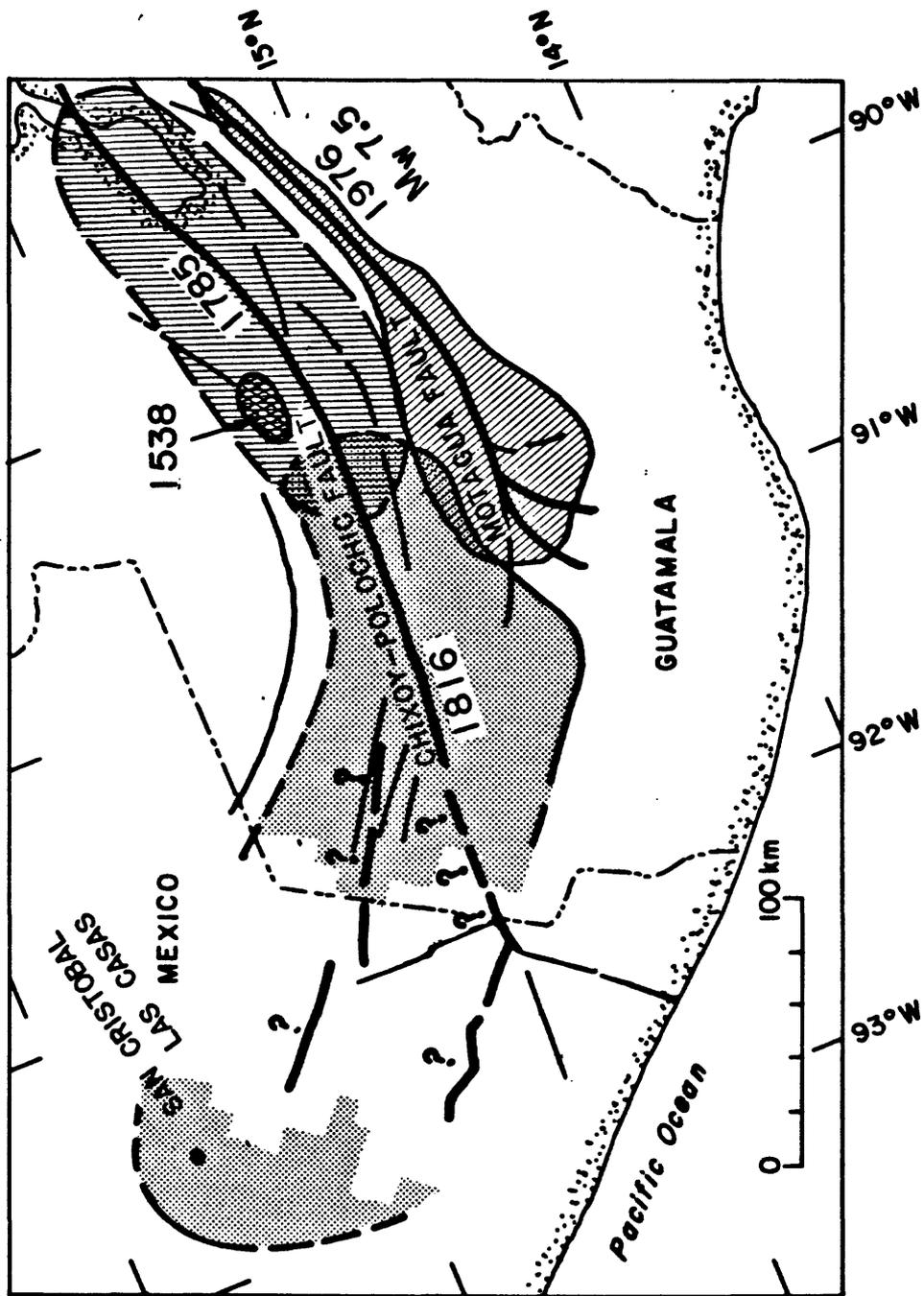


FIGURE 3

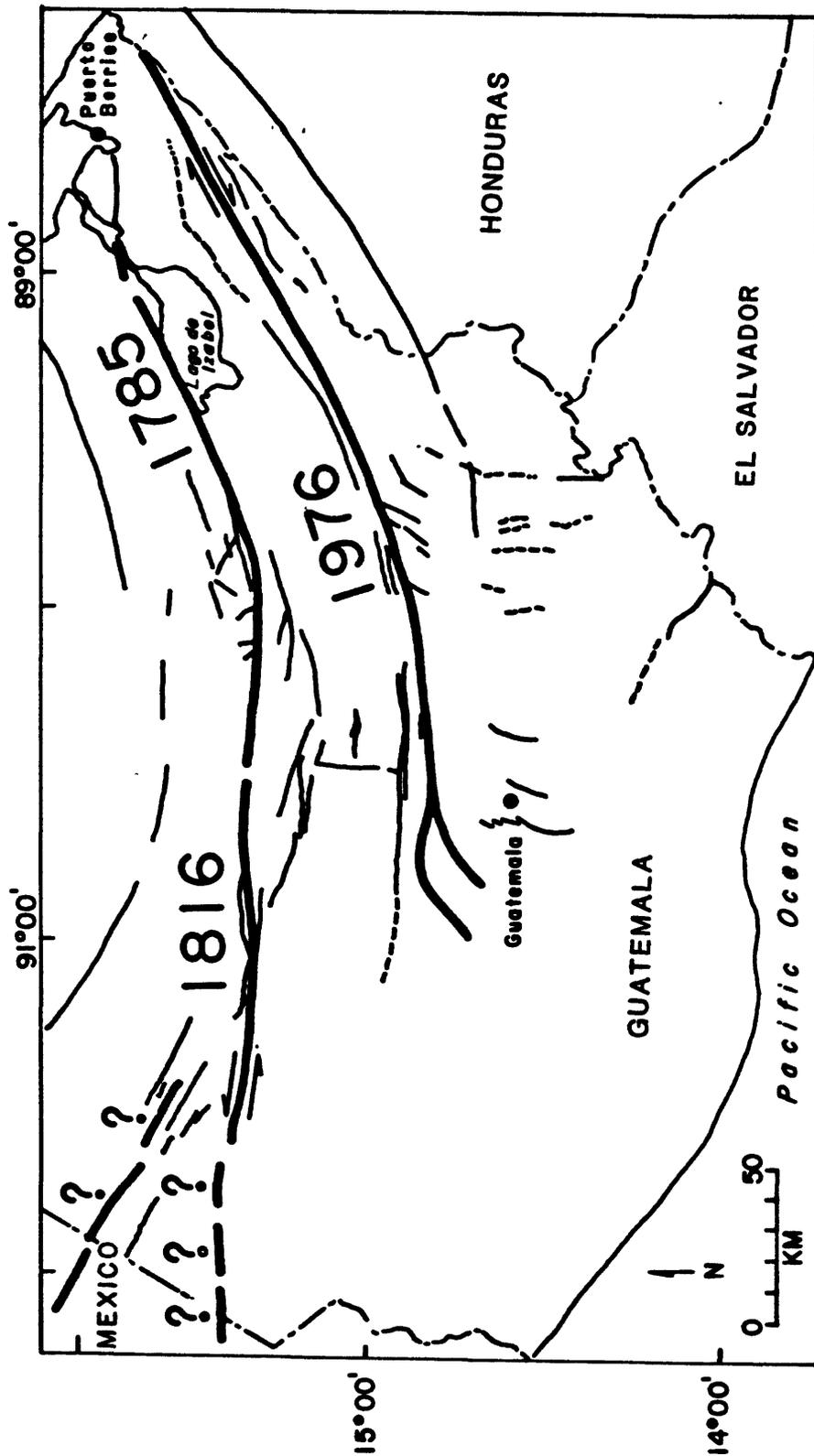


FIGURE 4

GUATEMALA

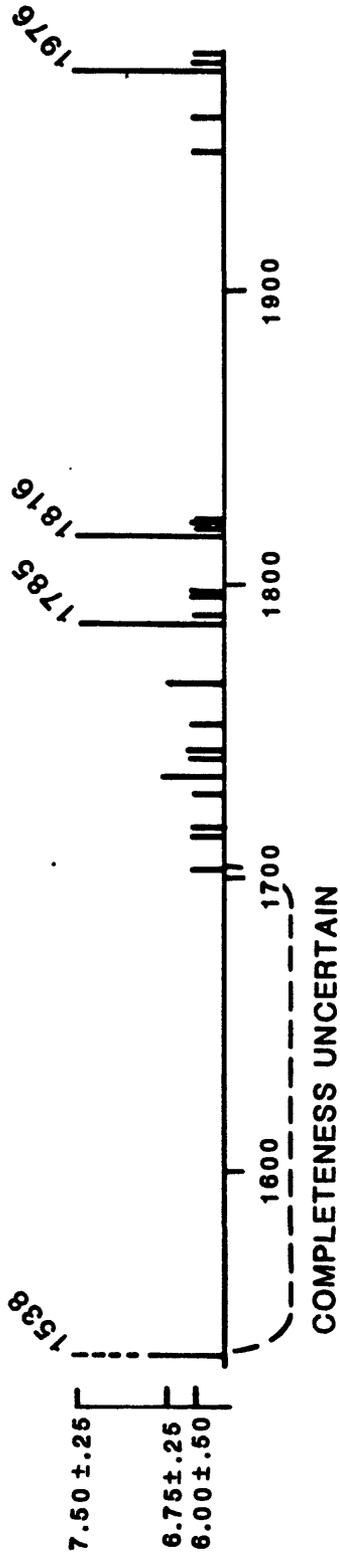


FIGURE 5

APPENDIX

Call numbers below that begin with "A" are for manuscripts residing at the Archivo General de Centro-America, in Guatemala City. Call numbers that begin with G are for manuscripts residing in the Guatemala section of the Archive General de las Indies, in Seville, Spain. The call number that begins with S. C. is for a manuscript residing at the cathedral in San Cristobal las Casas, in Chiapas, Mexico. See Figure 2 for locations.

Date of Earthquake	Town	Date of Manuscript	Reference or Call Number
1538	3 km east of San Juan Chamelco	1574	Cofradia Archive of San Juan Chamelco, reprinted Prensa Libre, 22 Dec. 1976 "The Aj Tziz Bal indians lived peacefully in a settlement one league [2 1/4 to 3 km] from an elevated hill [1522 mts] that is bounded at the eastern base by the Sotzil River. About the year 1538 this settlement was being governed by chief Pal Pop when there occurred a violent earthquake that crumbled a great part of the hill that they inhabited. After a council of the leaders, they decided to migrate to lands distant"
1702 or 1703	Cubulco	1703	A1.24-10217-1573:273 "The mayor, registrars, and principals of the town of Santiago de Cubulco of Verapaz province verify that on the occasion of the recent earthquake all of the main chapel of the church of said town was totally ruined..."
1713 Aug 12	Zacualpa	1714	A1.24-10225-1581:22-27 "...need to reconstruct the church of Espiritu Santo de Sacapulas [present day Zacualpa] destroyed by the earthquakes of August 12, 1713."
1714 May 5	Amatenango	1714	A1.24-10225-1581:540 "...the great earthquake that befell this town of Santiago Amatenango of the said province [Chiapas] on the 15th day of May of this year caused notable ruin to the roof and walls of the parroquial church..."
1728	Dolores Manche		A1-18805-2448 "...the principals of the town (of Dolore Manche) state that tthis town was left in very bad state...by the earthquake."
1728	Tactic	1729	A1.10.3-6836-329 "The principals of the town of Santa Maria de Tactic solicit economic aid in order to rebuild the church."
1733	Quetzaltepeque	1733	A1.10.3-31300-4047 "...we state that because of the great earthquakes that have been experienced in said province, the church of our town [Quetzaltepeque] was ruined to such an extent that it was left totally collapsed to the ground, and no fragment thereof can be salvaged."

Date of Earthquake	Town	Date of Manuscript	Call Number
1733	Chiquimula	1734	A3.16-17575-942:43
"Last year [1733] there occurred in this territory an earthquake so great that..it damage the church leaving it on the verge of collapse..."			
1733	Quetzaltepeque, Chiquimula, Santa Elena, San Luis Jilotepeque, and Ipala	1736	G:230
"...all of these [churches] were ruined by the recent earthquakes..."			
1733	Santa Catarina Mita	1770	A1.11-3540-175
"...church ruined...by a memorable earthquake..."			
1733	Jocotan	1738	A1-31315-4047
"Ask [economic] aid in rebuilding the church built in 1733...it completely collapsed in the great earthquakes..."			
1741	Coban	1742	A1.10.3-31319-4048:4
"The eyewitness inspection of the church, by the chief surveyor of Coban, found it left in very bad state by the earthquakes that occurred on the 15th of February of 1741...and is in danger or collapse if not repaired."			
1741	Cubulco	1745	A1.10.3-31336-4048
"The chief priest of the town of Santiago Cubulco certifies that the church and sacristy of the town are in a very bad state and requests aid for its restoration."			
1741	Tamaju	1745	A1.10.3-31333-4048 A1.10.3-39753-4652
(Information on the cost of rebuilding the church---the specific cause is not mentioned but the proximity in time and space, 20 kms, to the above damage at Coban make it seem probable that it was caused by the earthquake of 1741.)			
1743 Oct. 15	Chiquimula	1745	A1.11.25-46573-5439
"A strong earthquake ruined the walls [of the church] as extensively as the roof." "...on the 15th of October, 1743."			
1743	Zacapa	1744	A1.10.3-31331-4048
Document from the principals of the town of Zacapa requesting an evaluation "by the Archbishop's surveyor concerning the rebuilding of the church damaged in the earthquakes" of the 15th of October, 1743.			
1750 Mar. 8	Soloma	1750	A1.1-55084-6087:4
"The church collapsed from the continuous earthquakes that have occurred."			

Date of Earthquake	Town	Date of Manuscript	Call Number
1750 (1751?)	Chiantla	1754	A1.10.3-31354-4049
<p>"Father Eugenio de Mora...states that the holy church...was left gravely ruined by the earthquake...and is threatening dangerous consequences..." (The manuscript ascribes the damage to the "earthquake of San Casamiro", of March 4, 1751 which is well remembered because it caused considerable damage to the capital of Antigua over 150 km to the southeast. This damage in Chiantla, however, most likely resulted from the same earthquake which damaged nearby Soloma on March 8, 1750.)</p>			
1765 June 2	Chiquimula	1766 1767 1784	G:543 G:407 A1.11.25-3570-176
<p>"entirely ruined the two churches"... "Also ruined were all of the houses of brick, including those royal and clerical. Although some straw huts and some fortresses didn't fall, they remain so destroyed that general rebuilding is necessary."... "tremors continued until the month of August. Sixteen Indians and eight Spaniards were killed besides [those that died from the] epidemic that followed...and most of the rest were maimed"... "Six or eight hot springs occurred on the road to Zacapa." ... "All of the vicinity of the town out to 10 or 12 leagues (23 or 28 kms) in distance experienced landslides...Crevices were seen in both the valleys and flat lands."</p>			
1765	Camotan, Jocotan, San Juan Ermita, Jilotepeque, Jutiapa, Esquipulas, Quetzaltepeque, San Jacinto, Santa Elena, San Jose, San Esteban, Chiquimula, and Zacapa	1769 1777	G:743 A3.1-2220-1299:60
<p>Testimony concerning the pardoning of the tributes in view of the deaths of the natives of the towns of ... of the province of Chiquimula." [Some of these deaths may have been only indirectly caused by the earthquake. An epidemic is known to have followed this earthquake.]</p>			
1765	Santa Elena, Jocotan, and Zacapa	1777	G:562
<p>"I am neglecting the [churches] that are entirely ruined in the municipality of Chiquimula and I know for sure this is so ... for the chief church and also the one in Santa Elena, an annex town. In Jocotan I am sure the chief church is in the same state. In Zacapa I know for sure the same is true"</p>			

Date of Earthquake	Town	Date of Manuscript	Call Number
1765	Concepcion de las Minas	1770	G:644
"The mayor of Chiquimula de la Sierra in conjunction with the prelate propose methods of repairing the churches [of the province of Chiquimula] that were left deteriorated by the great earthquakes--as were the mines of Alotepeque [present day Concepcion de las Minas] totally lost."			
1765	Esquipulas	1767	A1.21-3539-175
"Some damage to the parroquial church, the house of the priest, and the sanctuary."			
1765	Valle de Santa Rosa	1774	G:660
..."although it did [not] cause any injuries, a small part of a hill slumped".			
1765	Antigua	1774	G:658
"The movement was...terrible, and impulses rang the bells of the cathedral...didn't cause any apparent damage or ruin to public buildings...caused slight ruin to some walls of the neighborhoods but nothing worthy of attention..."			
1765	Jalapa	1774	G:658
"The earthquake damaged and knocked off some of the tiles of the roof of the church."			
1785 Jan. 6	Coban	1785	A1.11.25-3723-181
"The pillars of the church need rebuilding since the earthquake of Los Santos Reyes [January 6]...inspite of earthquakes here in the past the church has survived them from the time it was built [1575] until now."			
1785	Rabinal	1785	A1.11.25-3713-181
Document concerning the rebuilding of the church damaged by the earthquake of Los Santos Reyes [January 6].			
1785	Tactic	1785	A.11.25-3715-818
Plans concerning the rebuilding of the church.			
1785	San Cristobal, Santa Cruz Verapaz	1785	G:603
"The earthquake of the day of Kings [January 6] of the year 85 [1785] ruined the church of San Cristobal and so badly damaged that of Santa Cruz that it was necessary to remove the roof and rebuild anew from the cornices...the church [of San Cristobal] fell totally to the ground..."			

Date of Earthquake	Town	Date of Manuscript	Call Number
1785	Cubulco	1785	A1.11.25-3716-181
"The governor and mayor of the town of Santiago Cubulco...state that our church was badly damaged by the great earthquake of the early hours (madrugada) of the 7th of January of this year, and is threatening the collapse of the dome and main chapel."			
1785	Castle San Felipe	1785	G:879
"The Castle of San Felipe del Golfo experienced a strong earth movement which was also felt in this Capital [Guatemala City] the night of January 6 of this year which ruined to pieces most of their fortifications" "experienced in various locations in the realm..."			
1786	Chichicastenango	1786	A1.11.25-45922-5398
"I found myself here on Thursday, being the confessor in the church when it was shaken and all of the tiles of the facade fell, and the main arch was distorted about half a meter [media vara], damaging those tiles."			
1786 (1783?)	Chinique	1810	A1.10.3-2396-110
"It was decided to ask permission to bless and begin using the chapel that was rebuilt in this valley destroyed in 1783." (This probably refers to the same earthquake mentioned above since Chinique is only 14 kms from Chichicastenango, the error in date is being attributed to the passage of 24 years before the writing of this manuscript.)			
1795 Dec. 29	Chiantla	1797 1805	A1.11.25-24631-2804 A1.24-55307-6091:93
"Because of the earthquakes that happened on the 29th of December of the past year of 95, [1795] the church,...although it didn't collapse, the roof was completely lost and the tower unusable, so that it needs to be rebuilt."			
1795 Nov. 8,17	Huehuetanango	1801	AEG:A4.17
"The mayor...verifies that the walls of the church were left...in a sad state and out of plumb...[and some time later] one fourth of the length of the walls fell to the plaza."			
1795	Huehuetanango	1805	A3.16-4923-247
"The community of Concepcion Huehuetanango asks exoneration from paying the tributes because of being occupied with the reconstruction of the parroquial church, ruined by the earthquakes 10 years ago."			
1798 (or 1799) July 2	Lanquin	1799	A1.11.25-3732-182
"...church ruined on July 2...by an earthquake that occurred...in said town."			

Date of Earthquake	Town	Date of Manuscript	Call Number
1804	San Cristobal las Casas, Chiapas	1978	Ruiz
<p>"In the first and second decade of the 19th century, in the years 1804, 1816, and 1817 there occurred earthquakes and, as usual, obligated the reconstruction of the Cathedral: In 1804 the bishop...not only repaired the damage but rebuilt the roof of the central nave anew and replaced the tiles with new ones." (This earthquake could have been generated by the subduction zone, although the earthquake of 1816, which damaged this same cathedral, is definitely from the strike-slip fault region.) Eduardo Flores Ruiz, La Cathedral de San Cristobal las Casas, Chiapas, 1528-1978, Publicacion del Area de Humanidades de la Universidad Autonoma de Chiapas, 1978, p. 27.</p>			
1816 Jul. 22	Alta Verapaz, Baja Verapaz, Quiche, Totonicapan, Huehuetenango, and Chiapas, Mexico	1816	White
<p>Damage from San Cristobal Verapaz to San Cristobal las Casas, Mexico. Estimated magnitude M 7.6. See White (1983).</p>			
1817	San Cristobal las Casas	1817	S.C., VI.A.2
<p>"...in the report verification was given of the ruin caused by the earthquake of the 30th of January of this year to the sacred cathedral of this city</p>			
1820 June 6	Salama	1821 1821	A1.11.25-7997-384 A1.1-57284-6931
<p>The mayor writes to the archbishop that "the neighborhoods of the town of Salama wish to rebuild the parroquial church, ruined by the earthquakes that occurred on the 6th of June, 1820".</p>			
1821 May 6	Ilotenango, Jocopilas	1821 1821	A1.11.25-8208-393 A1-24675-2806
<p>The parish priest declares that "on the 6th of May of 1821 there occurred an earthquake so great that I have been left without churches and quarters in both town of my charge (San Antonio Ilotenango and San Pedro Jocopilas)".</p>			
1821	Jocopilas	1821	B3.6-985-47
<p>"...need to rebuild the parroquial church and the conventual house, destroyed by the earthquake of 1821".</p>			

Date of Earthquake	Town	Date of Manuscript	Reference
1881 August 13	Chinique	1930	Montessus de Ballore
At Chinique, department of Quiche, several and continuous strong shocks. The principal at 12:30 was felt somewhat strongly at San Marcos and less at the observatory in Guatemala (City).			
1881 June 3,4	Coban	1888	Montessus de Ballore
At Coban: two light shocks, on the 3rd at 20:10 and the 4th at 20:55			
1882 March 2	Salama	1883	Rockstroh
"During the ... night there were 5 moderate shocks in Salama."			
1930 January 20	Verapaz and Huehuetenango	1969	Vassaux
They felt a strong shock that affected the region in the north and north-east of the Republic, Alta and Baja Verapaz and Huehuetenango.			
1945	Quirigua	1945 Oct 3	Dispatch no. 689 from the U. S. Embassy at Guatemala
"The Construction experts sent from the States have now made a careful inspection of what is left of the Quirigua Hospital and pronounced it completely unuseable." After the second shock the experts were reporting "that the building was useable, when the third shock struck and it was practically broken up while (they) were looking at it."			
1976 February 4	Motagua Valley	1976	Espinosa, U. S. Geol. Survey Prof. Paper 1002
1978 July 29	Tecpan	1978	INSIVUMEH
1980 August 9	Puerto Barrios	1980	INSIVUMEH
1982 Sept. 29	Chanmagua	1982	INSIVUMEH