PD-AAX-182

PROGRESS REPORT

TO

THE AGENCY FOR INTERNATIONAL DEVELOPMENT

ON

A PROJECT TO ESTABLISH AN

EARTHQUAKE HAZARDS REDUCTION PROGRAM

IN GUATEMALA

PREPARED BY

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U.S. GEOLOGICAL SURVEY

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Introduction

Motivation to establish an earthquake hazards reduction program in Guatemala: 9 damaging earthquakes in the last 9 years:

1976 Feb 4	Motagua Valley	M 7.5	22,000 dead	100,000 injured
1978 Feb 22	Retalhuleu	M 6.2	2 dead	Several injured
1978 Jul 26	Tecpan	M 5.0	5 dead	12 Missing
1978 Aug 18	Mazatenango	M 5.4		Several injured
1979 Oct 9	Santa Rosa	M 5.0	40 injured	150 houses damaged
1979 Oct 27	Escuintla	M 6.8	4 dead	20 injured
1980 Aug 29	Puerto Barrrios	M 6.5	2 dead	Many injured
1982 Sept 29	Chanmagua	M 5.5	3 dead	550 houses damaged
1983 Dec 2	San Marcos	M 7.1	light but widespread damage	

The overall goal of this project is to establish an earthquake hazards reduction program in Guatemala that will undertake the ongoing study of:

1) Where in Guatemala do destructive earthquakes occur
2) How often do earthquakes recur at each site
3) What types of effects (shaking, liquifaction, landslides, tsunamis, etc.) can be expected at each site from earthquakes at different sites.
4) How large can these effects be at each site.

The objective of this first phase is to begin accumulating the basic data needed for earthquake hazard analysis and provide technical guidance and training for Guatemalan scientists and technicians of INSIVUMEH so that the earthquake hazard analysis may become an ongoing program in Guatemala. The basic data for earthquake hazard analysis is obtained by:

1) Compiling detailed descriptions of the damage caused by past earthquakes to determine where (generally), when they occurred, and the size and the effects of each earthquake.
2) Maintaining a high-gain seismograph network to explore for and locate (exactly) active faults and to provide detailed up to the moment information on the status and activity levels along each fault.

Included in the technical guidance is:

1) Training in the operation maintainance of the seismograph network.
2) Instruction in the routine micro-earthquake data analysis techniques in order to produce a daily micro-earthquake catalog.

Funding of this project has permitted Guatemala to get a nation-wide program of the ground that it first proposed and attempted after the disasterous 1976 earthquake. The progress of this project during the last 12 months has been excellent and is summarized in the following pages.

This report is organized according to the items A through H of the "Scope of Work" in the PASA agreement, as presented on the following page.

Scope of Work

The Scope of Work according to the PASA agreement IGT-5542-P-1C-3161 between the USGS and AID specifies that the initial phase of this project include the following elements:

a. Repair and renovation of existing high-gain seismograph stations in the field.
b. Repair and renovation of the central recording and analysis site at INSIVUMEH.
c. Expand production of micro-seismicity maps to include the coastal, eastern, western and Chixoy-Polochic regions not currently covered adequately by the national network.
d. Begin producing Focal mechanisms for the larger events.
e. Begin identifying active surface faults from the micro-seismicity.
f. Begin specialized training for five INSIVUMEH electronic technicians with at least 30-day seismograph installation and repair courses at USGS facilities.
g. Gather available data on historical earthquake damage, and from this data:
    1. Produce location maps of historically destructive earthquakes within or adjacent to the borders of Guatemala.
    2. Produce recurrence, or repeat time estimates for those areas where the historical records are adequate.
    3. Begin preparation of iso-accelleration maps as data from renovated network is compiled. (Completion would be part of a second phase of this project).
h. Procure equipment and materials necessary to repair and renovate the INSIVUMEH seismic network.

(A) The philosophy with the repair and renovation of the field stations was to make them as reliable as possible. Most of the remote stations have suffered over 70 percent downtime. Problems included dead batteries, lightning strikes, radio interference from nearby illegal transmitters, VCO drift, seismometer grounding problems, and some wiring errors. We replaced the batteries with rechargeable batteries and installed solor panels to continususly recharge them. Lightning problems were reduced by 80 percent by sheathing the seismometer cable in flexible metal Boudin conduit. We attacked the radio interference problem by using a frequency scanner to search for occupied frequencies at both sending and receiving sites, then using VHF channels that were found to be un-occupied at both sites. In several cases all VHF channels were occupied at one site or the other so UHF radio links were purchased. We replaced the old VCO's with new J302 VCO's that are very frequency-stable, much less sensitive to temperature variations, have better environmental packaging, and don't need separate batteries. The S-500 seismometers were replaced with Mark Products L-IV seismometers that don't have the grounding problems. Wiring at each site was simplified and standardized and all connectors soldered instead of crimped as before.

The above renovations should realistically reduce the downtime of remote stations from over 70 percent to about 10 percent, reduce the number of required maintainance visits by 70 percent and improve the signal quality by 100 percent. A major additional benefit is that the USGS will provide INSIVUMEH with free servicing and repair of VCO's, and replacement of damaged seismometers at only 100 dollars each.

(B) We have improved the reliability at the central recording site by bringing up the Develocorder recording system. Since it records 17 stations at once, it can be thought of as a back up to all 17 single station helicorder drum-recorders. The great advantages of the Develocorder include 5-fold increase in timing precision, compact storage, and ease of use. A satellite- sychronized clock was installed at the recording site for continuous precise time on all records.

All discriminators were realigned and all receivers were checked and repaired or realigned. Much of the wiring was simplified and standardized to facilitate the checking of signal strength and quality.

Several new items of laboratory test equipment were delivered and some existing equipment repaired so the INSIVUMEH technicians may check and realign or repair most of the seismological equipment there in Guatemala.

(C) The network was expanded with the installation of a two-component station near the Mexico border at Ocos and a standard vertical-component station on Siete Orejas. A vertical conponent station was installed near the Salvadoran border at Moyuta and a horizontal will be added there in the next six months. These three additional stations and the renovation of the other several coastal stations now permits the location of earthquakes in the coastal region with about 10 times more precision than before. We estimate that by the end of 1985 we will have accumulated enough precise hypocenters in the micro-seismicity catalog of coastal Guatemala to be able to contour the down-going sea-floor slab and perhaps identify active and quiescent regions.

Other stations in eastern Guatemala and in Huehuetenango province have been brought into full-time operation and will allow the routine location of epicenters in these two unstudied yet historically active regions.

(D) Focal Mechanisms: The network is now at a good enough level of operation to begin gathering data for the production of focal mechanisms.

(E) Preliminary results from the cataloging of micro-seismicity show that the following surface faults are active:

1) The western segment of the E-W striking de Chama fault
2) The eastern segment or extension of the de Chama fault, near Belize
3) NNW-SSE trending faults near Rio Usumacinta, between Mexico and the Peten
4) E-W striking transcurrent faults near Cahabon (detected by Chulac net).
5) Normal NW-SE striking faults near Momostenango
6) A NE-SW trending oblique-normal fault at Tecpan
7) A NE-SW trending oblique-normal fault at Chimaltenago
8) A NE-SW trending oblique-normal fault at Aquas Calientes
9) Chanmagua and similar NW-SE striking normal faults near the Motagua
10) Volcanic chain transverse faults between Lake Atitlan and the Salvadoran border

(F) Training of Guatemalan Personnel

Training for INSIVUMEH technicians was provided in Guatemala from February 10 through March 20, 1984 by Ronald Kaderabek of the U.S. Geological Survey. He provided hands on training in the maintainance and repair of standard seismograph field stations. This included the calibration or repair of UHF and VHF radio transmitters, voltage-controlled oscillators and seismometers and the testing of batteries, solar panels, and antennas.

During May 1984, two of the technicians, George Solares and Luis Garcia, and their chief, sub-director Eddy Sanchez Bennett, were brought to the U.S. Geological Survey laboratory in Menlo Park, California for three weeks of additional intensive training on base station maintainance. This included the repair and calibration of UHF and VHF receivers, discriminators, helicorders, and the Develocorder. Special short courses were provided on portable seismographs and strong motion instruments also. It should be noted that all of this instruction, which represented approximately $3,000 of time for U. S. Geological Survey technical staff, was provided without charge to the project.

This training now permits the INSIVUMEH technicians to maintain and repair almost all of the seismic equipment without U.S. Geological Survey help, although the U.S. Geological Survey has made a standing offer to repair any discriminators, VCO's and Motorola radios free of charge by mail, and will replace any damage seismometers for only 100 dollars. During the eight months following this training the technicians demonstrated an increased skill in station maintainance by keeping more stations operating than ever before, although the target, of 25 stations operating correctly with an outage rate of only 10 percent, has still to be reached.

During July and August of 1984, one Guatemalan scientist, Mr. Edgar Rene Quevec, came to U.S.G.S. offices in Menlo Park, California for six weeks of training in intermediate level seismology. Hands on training included analysis of old seismograms, location of critical events using impoverished data sets, and determination of "b-valves", energy release, magnitude, and focal mechanism. It should be noted that this training involved about $6,000 of time by U. S. Geological Survey scientists but was provided at no charge to the project. During this time we also funded a trip for Mr. Quevec to attend the Volcanic Hazards seminar at the Hawaiian Volcanic Observatory. This seminar was very useful to Mr. Quevec, covering practical basics of establishing a volcano monitoring network. He also became aquainted and interacted with most of his counterparts from the rest of the western hemisphere. At the end of Mr. Quevec's visit to California, we funded a two day visit for him to the Kinemetrics factory in Pasadena to study the basic theory and operation of strong motion accellerographs.

(G) Catalog of Historical Earthquake Damage

There are several existing reports that list dates for historical earthquakes in Guatemala but they generally contain little information on the extend and levels of damage sustained for any sites other than the capital. Without data on the levels of damage over a broad area it is impossible to determine where the earthquake originated or reasonably estimate the true magnitude.

We therefore made our own extensive search for original documents that might give eyewitness discriptions of the actual earthquake damage. About 1/2 man year of work was committed to this search during which time about 1500 manuscripts were inspected at the Colonial Archives of the Indies, in Spain. and local church, government and newspaper archives. About 150 of these describe earthquake damage to some degree. We compiled the information into two separate catalogs the first describes only the earthquakes to the northeast of the volcanic chain these earthquakes are all shallow ($z < 20$ km); the second describes the earthquakes along the coast and the volcanic chain and contains a mix of deep and shallow earthquakes. We have also micro-filmed all of the old seismograph records produced by the low gain station at Guatemala city between 1919 and 1967 and many of these records have been examined to establish distance, depth and magnitude of critical events during this period.

Preliminary results from this historical research demonstrate that the following surface faults are historically active:

1) The Chixoy-Polochic fault is about as active (and hazardous) as the Motagua fault: a major rupture $M \sim 7.5$ every ~ 200-700 years.
2) The Chixoy-Polochic fault between Lago Izabal and Tactic, though geologically active, will probably only experience earthquakes with $M < 6.0$ during the next 100 years.
3) The Chixoy-Polochic fault from San Cristobal Verapaz to Cuilco may become more active during the next 100 years, perhaps a M=6 per decade and possibly even a large event of $M \sim 7.4$.
4) The region north of Chiantla, southeast of Barillas (1971, 1959).
5) The Rio Dulce strike-slip fault is very active with M 6.5 earthquakes every 30 to 60 years.
6) N-S trending normal faults throughout Chiquimula Province
7) The Jalpatagua fault
8) The Cubulco - Salama thrust fault
9) The Zacualpa - Jocopilas extension of Motagua fault
10) The Mixco normal faults
11) The Santa Catarina normal fault
12) N-S trending normal faults through Santa Rosa Province

We can set upper limits on the size of an earthquake, the Maximum Probable Earthquake (MPE), that can be generated by certain faults by a) using the historical record and b) inferring from other faults of the same type and dimensions.

1) Earthquakes on the subduction zone between the trench and 65 km deep have MPE of $M \leq 8.0$.
2) Earthquakes below 65 km on the subduction zone have MPE ≤ 7.4.
3) Earthquakes within 10 km of the volcanic chain have MPE of $M \leq 6.5$.
4) Earthquakes on the Motagua and CPF have MPE of $M \leq 7.6$.

(H) Equipment Purchases:

To date $33,986 have been spent from project funds for equipment repairs and the acquisition of new equipment. This is appoximately one third of the total budget for this project. All of this equipment is now the property of the INSIVUMEH and will remain in Guatemala. It should be noted that the U. S. Geological Survey donated about $46,670, including $32,000 of new VCO's, of additional equipment to the project, to remain in Guatemala also.

(a) Repair and Renovation of Field Stations

	Cost to USGS, $	Cost to project, $
(Scala) UHF Antennas		784
(Howard Jones) Batteries		1000
(Arco) Solar Panels and brackets		3240
(Monitron) UHF transmitters		4220
(Mark IV) Seismometers		5400
J302 VCO's 32 ea	(33,000)	1000
J302 DCDC Converters	(800)	0
Repair Monitrons transmitters		1005
Repair Motorola transmitters	(1,000)	0
Bearcat Frequency Scanner		400
Frequency Counter	(300)	0
Frequency Counter Prescaler		120
Lighting Arrestors	(250)	0
Portable 5 hz calibrator	(100)	0
VCO deviation calibrator	(100)	0
Misc cables-connectors etc		2000

(b) Repair and Renovation of Base Receiving Station

	Cost to USGS, $	Cost to project, $
VHF (5) Receivers (new)		2820
VHF Receivers (repair)	(2000)	1000
Discriminators(repair)	(500)	0
Helicorder Pens		540
Develocorder parts		150
Fixer and developer		149
Kodak 35 mm film		600
Kodak film reader	(500)	0
Micro-film old records	(5000)	0
Satellite synchronized clock		3312
Cushman receiver monitor repair		800
Non-Linear Systems portable oscilloscope		466
Hitachi oscilloscope		744
Wavtek function generator		432
6 Sperry tiltmeters		3000
4 extension (creep) meters	(1000)	0
Computer tapes 6 ea	(120)	0
AGU books		162
Battery Charger		82
1 Hewlett-Packard HP-85 Computer	(3000)	0
Fluke Multimeter		350
Bird UHF plugin		200

Total cost charged to the project:	$33,986
Total cost of equipment including donations by USGS:	$80,656
Additional equipment locally procured: 2 Vehicles, 4 wh-drive	$20,000

Volcanic Hazards

INSIVUMEH is responsible for monitoring volcanic hazards in Guatemala, but little is being done at the present time. As part of the May 1984 training course at Menlo Park, David Harlow accompanied Ing. Sanches, sub-director of INSIVUMEH, and Ing. Gonzalez of CIG, El Salvador on a two day visit to the USGS's Cascade Volcanic Observatory (CVO) in Vancouver, Washington. CVO's promary mission is to provide an early warning of eruptive activity at St. Helens. They talked to several scientists who are in charge of the various geophysical and geological programs at Mt. St. Helens with the purpose of learning what steps can be taken now to begin a volcano hazards reduction program. One of the most reliable harbingers of eruptive activity is an increase in the level of seismic activity. Guatemala's seismograph network, therefore, can be used to monitor the eruptive potential of their three active volcanoes. Publications describing the kinds of seismic activity that preceeds volcanic eruptions were given to Ing. Sanchez and Ing. Gonzalez.

Interactions with other Government and Public Agencies

One of the most critical elements of this program is the development of an organism within Guatemala that is responsible for continuing the work begun under this program, to continue studying and analyzing the seismic and volcanologic hazards, modifying the assessments as data dictate, and insuring that this information is passed to the appropriate parties such as the Office of Emergency Preparedness, architects, design engineers, and Office of Public Works that will need this data for planning.

Toward this end two conferences were organized to present the work being done under this program to the Guatemala organizations. The first was directed at the Union of Architects and Design Engineers. At this conference I delivered a one hour presentation on newly discovered historical earthquake data. One particularly important piece of data discussed was the discovery of a very large earthquake on the Chixoy-Polochic fault that occurred in 1816. This data demonstrated conclusively that the Chixoy-Polochic fault was active, indeed as active as the Motagua fault, that killed over 22,000 people in 1976. The second conference was open to the public and twelve different Guatemalan agencies were invited (and came). Again the significance of this 1816 earthquake was discussed - it was specifically stated that the Chixoy-Polochic definitely presented a large seismic hazard to people and public works in the area including the Chixoy Dam Project. About six months later, seismic activity on the Chixoy-Polochic fault damaged the penstock of the $800 million Chixoy Dam Project. This earthquake-induced damage has caused at least a 13 month delay in the opening of the dam to energy production, or at least $80 million of economic damage to date.

Following these events, the dean of Guatemalan architects, Mr. Jose Asturias who attended our second conference, organized a nationwide government-sanctioned conference on natural hazards in Guatemala. At this conference INSIVUMEH was given the official mandate to study and analyze geologic, seismic, and volcanic hazards for the country as a whole.

Cooperation between Guatemala and neighboring countries

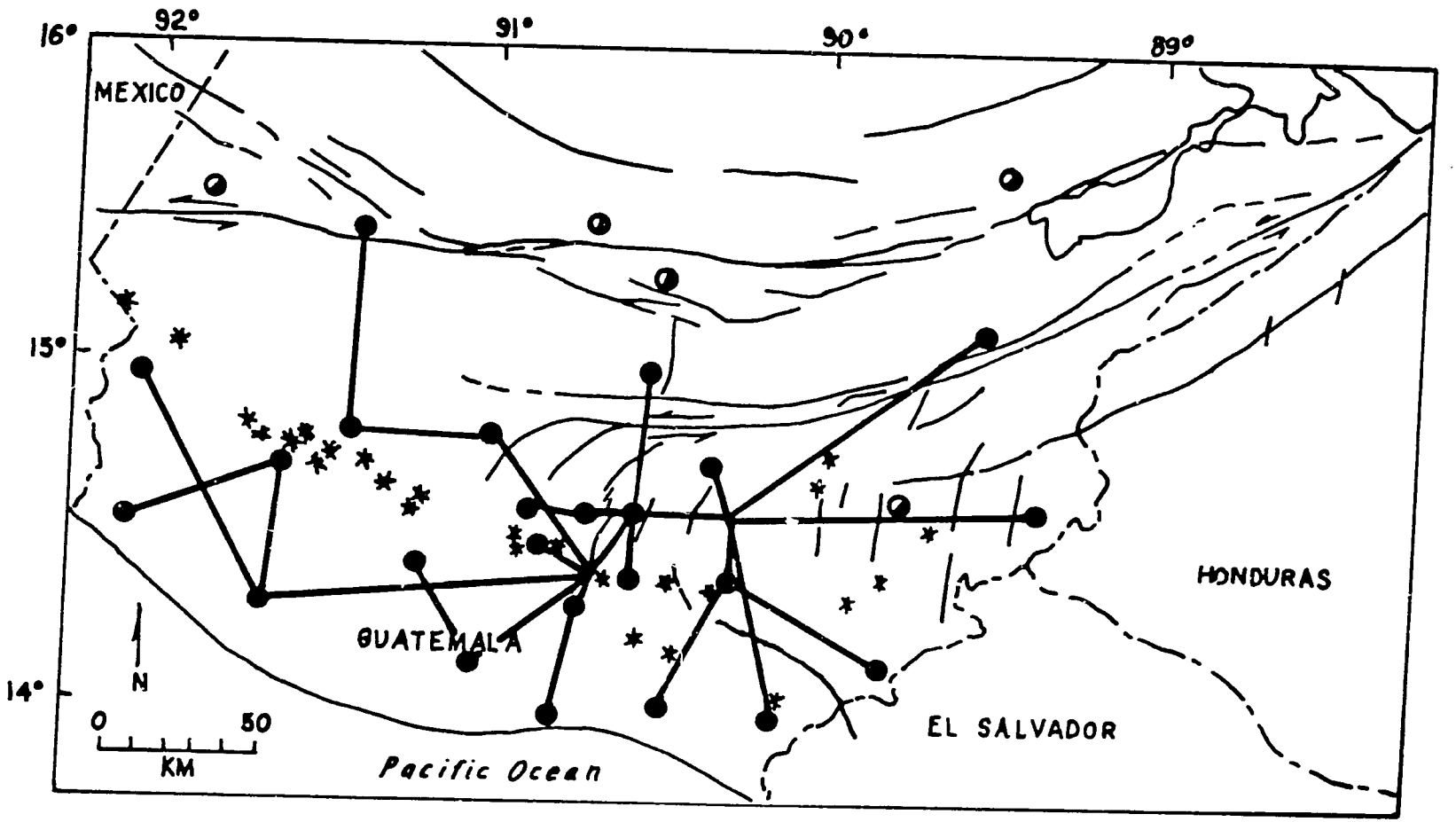
Mr. Eddy Sanchez, Subdirector of INSIVUMEH in Guatemala and an electronics technician, accompanied David Harlow of the U.S.G.S. to El Salvador in October 1983 and March 1984. Mr. Sanchez has several years experience with seismic instruments and hs is proividing technical training in El Salvador for this project. During the field trips to El Salvador, discussions between Mr. Julio Bran and Mr. Jose Gonzales of CIG, El Salvador, Mr. Sanchez, and David Harlow laid the ground work for technical and scientific cooperation between El Salvador and Guatemala. An exchange of letters between the two Ministers of Public Works in November 1983 officially endorsed the cooperative program. This cooperation represents a significant step in addressing the regional aspects of earthquake hazards. Zones of seismic activity cross the boundary between El Salvador and Guatemala. In several instances, the same large earthquakes have caused heavy damage in both El Salvador and Guatemala. Qualified personnel are in short supply and if applied regionally and not just nationally, their talents can be employed most effectively.

In December of 1984 the two of the Guatemalan scientists most closely associated with this program travelled to the Panama for the first regional conference on Central American and Caribbean tectonics and hazards and presented the preliminary results obtained so far by this program. During this trip these scientists were again able to consolidate professional relationships that will be critical for continuing regional cooperation and progress towards the reduction of seismic hazards.

FIGURE 1. The Guatemala National Seismograph Network. Solid dots represent stations that have been renovated or installed under this program and are currently operating. Half-filled circles are stations that are installed in the field but are not yet radio linked to Guatemala City. Volcanoes (*) and major faults (thin lines) are also shown.

FIGURE 2. Micro-seismicity of Guatemala. Recent micro-earthquakes with depths of less than 20 kms. are shown. The size of the symbol depends on magnitude as shown at lower right. The concentration of epicenters around Guatemala City (near the center of plot) is partly due to the continuation of aftershocks there from the 1976 earthquake but is also partly due to the fact that epicenters far from the city have not been recorded well because of the high outage rate of stations farther out.

FIGURE 3. Historical Earthquake Damage. Stipled areas show the areas of damage due to just the shallow earthquakes uncovered by this program, together with the most recent earthquakes of this century. This figure demonstrates that Guatemala is one of the most seismically active countries in the world.



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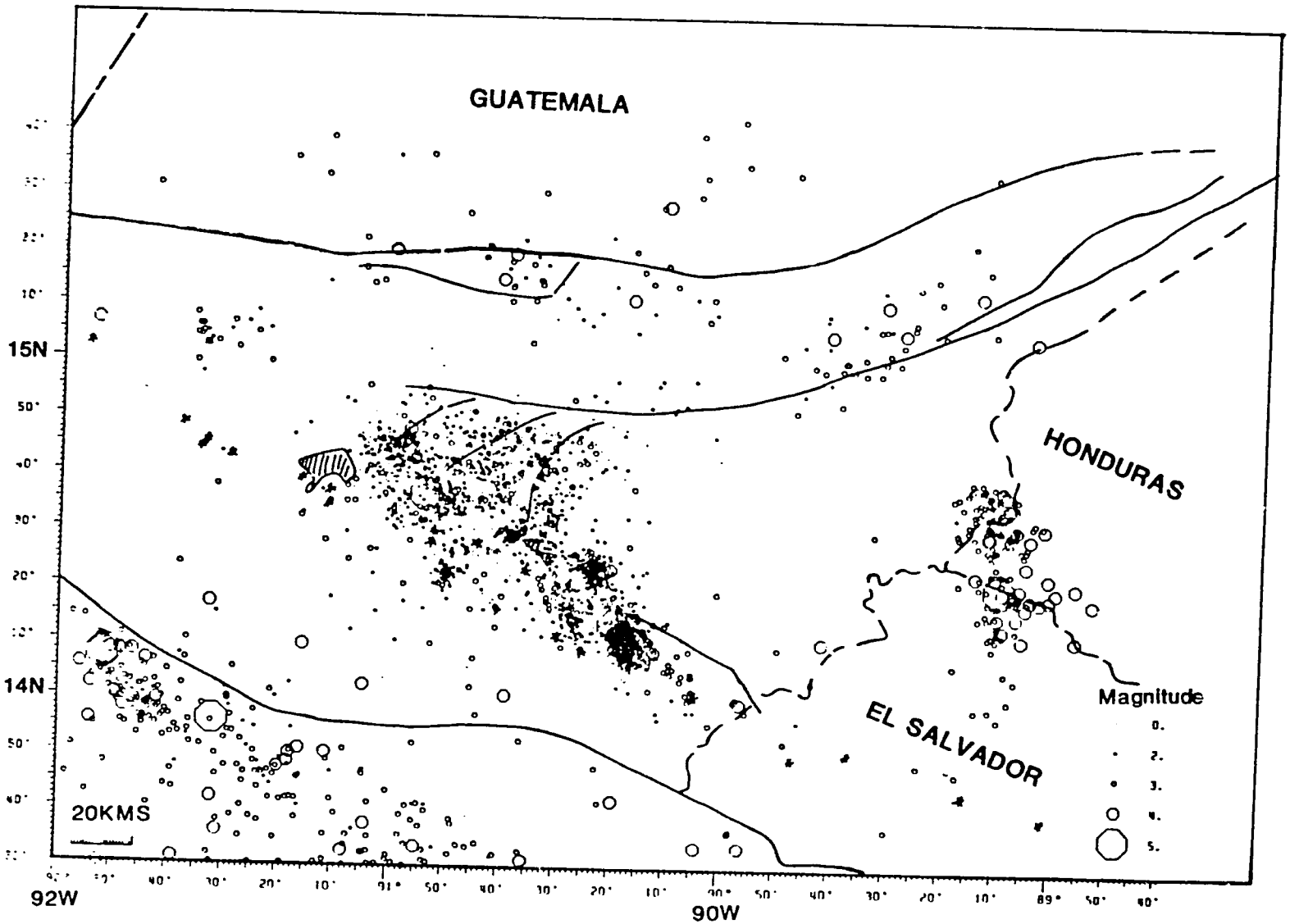

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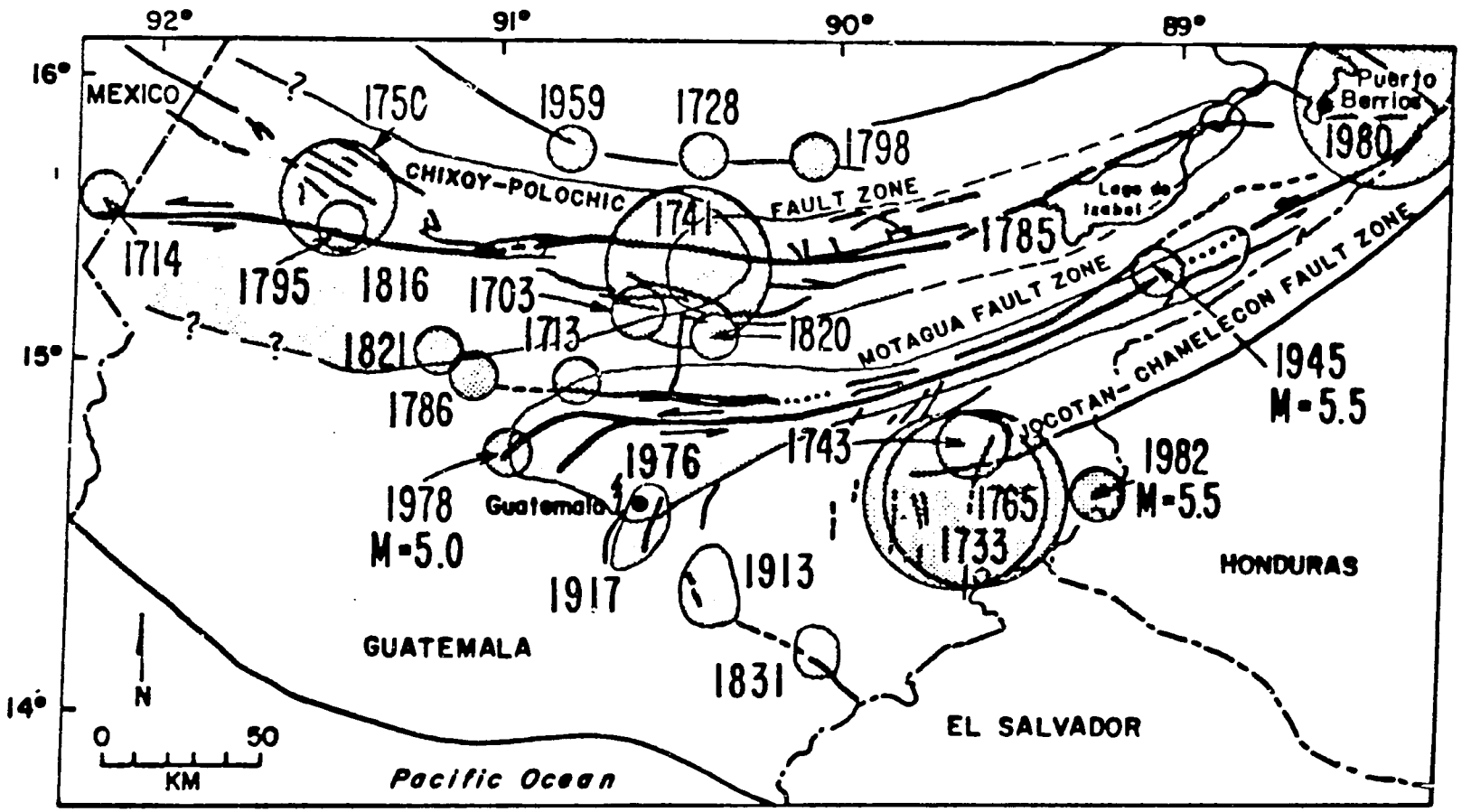

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