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RECONNAISSANCE VISIT TO THE FEBRUARY 1976 GUATEMALA EARTHQUAKE SCENE

by

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C O N T E N T S

INTRODUCTION

During 1974/75 several study and planning groups were appointed in the Division of Seismology and Geothermal Studies of the Earth Physics Branch of the Dept. of Energy, Mines and Resources. The Study Group on Post-earthquake Contingency Planning, amongst other things recommended strongly to send a team of perhaps one to three persons into a "suitable", i.e. reasonably located major urban earthquake disaster area, in order to observe other reconnaissance teams in action and thus to learn from their experience for a possible future Canadian earthquake scene. (Seismology Division Internal Report No. 75-2). Dr. Milne of the Victoria Geophysical Observatory was responsible for arrangements with the Earthquake Engineering Research Institute (EERI), according to which the observers from our Division would be contacted by EERI and invited to participate in the case of a major earthquake which warranted an investigation team by that Institute. Our observers would then join the EERI group, profiting from their logistics and experience.

After the major earthquake struck Guatemala on 4 February 1976 shortly after 0900 GMT, EERI president Henry Degenkolb phoned our Ottawa headquarters to indicate EERI's intent to send a group to Guatemala, and to give their approximate travel schedule and rallying point in Guatemala. Within less than 24 hours, EPB management decided to send one man on this occasion. Passports and general vaccinations had been brought up to date in the fall of 1975, but visa uncertainties and tight airline bookings caused some delay. The

writer finally left Ottawa 64 hours after the earthquake and arrived at Guatemala airport 88 hours after the first major quake. These figures are insofar relevant as they show the difficulty of timeliness of even a single man travelling without instruments. In this particular case, a major aftershock had occurred 57 hours after the main shock and the EERI group had assembled about 24 hours before the writer arrived, so that an important observation and part of the organizational phase of the expedition was missed. I, nevertheless, consider the one-man Canadian expedition as successful as could be expected: four days were spent in close association with the EERI reconnaissance team, meeting and observing members of some other groups during that time, and an additional day alone after the departure of the EERI group, making further contact with other investigators.

This report is deliberately a mixture of personal travelogue, general observations, factual information on this particular earthquake and its effects and recommendations for further Canadian observers or for investigation teams on a Canadian earthquake scene. A scientific report could not be written by an observer jumping from one project to another for 5 days; a set of handbooks on what to look for and how to report it has already been published by EERI, and the closest agreement on a divisional manual of instruction was composed by the initially mentioned study group. Details of reconnaissance missions will almost certainly vary from event to event and much reliance must be placed on the experience, ingenuity and dedication of the personnel involved.

LOGISTICS

Sequence of Personal Travel and Reconnaissance. For the record and assistance of possible later missions I include a short account of pre-departure problems and worries. On my checklist I noted in order of approximate importance these items: passport and visa, airline reservations and ticket, additional vaccinations, suitable baggage, photographic equipment, finally an international driver's license.

External Affairs very definitely advised to travel on Special Passport, but issue of this document seemed to depend on the availability of a visa. This could only have been obtained by visiting the consulate in Montreal in person, or by messenger. No official information was available from there, since the consulate did not answer the telephone; a vicious circle. Many cross-checks with officers of CIDA finally satisfied our Administration and presumably External, that a visa could be obtained at the Guatemala border, and the special passport was issued. I would probably have travelled on my regular passport, risking refusal of entry at the border, but this would clearly be a personal compromise between the need and desire for an early departure and observation of regulations. It turned out that a visa was not required; instead a tourist card was bought at the Miami desk of the Guatemalan airline. A week later I heard a rumour that the border had then been closed to unofficially travelling foreigners.

Airline reservations were a problem insofar, as Air Canada flights to Miami are generally heavily booked during this season. Regular channels through CTS did not prove of much help but a personal contact produced quick results. In fact, I might finally have been able to leave Ottawa as much as 1/2 day earlier, without running into other time problems, had I not set Saturday afternoon as the target for arrival in Guatemala, as given by the EERI communication. In conclusion, although a prepaid CTS ticket is a comfort, obtaining it may cause delays, as does insistence on reservations. If speed is valued, a personal credit card and standby status should not be overlooked.

A check with health services brought the recommendation of an additional gammaglobulin injection, against hepatitis and other viral infections. This was obtained and was probably useful.

Selection of proper baggage was complicated by the uncertainty about conditions to be encountered. I chose packsack with sleeping bag and mattress, 15 lbs. of concentrated food, canteens of Canadian water. Everything was found to be useful, but most of the food was contributed to relief operations. On one or two occasions I was sorry not to carry some more formal clothing, but this was not serious. The more experienced and/or civilized American engineers carried suit cases, but also sleeping bags.

Some camera equipment was loaned from the EPB photo unit. Well-tested equipment, familiar to the user is very strongly advisable. I carried one 35 mm camera from our photo unit which I had used before, with a 50 mm and a 28 mm objective, built-in lightmeter working

off a battery and one spare battery. Mr. Gelinas had recommended 64 and 25 ASA film for the expected high position of the sun. This is useless for only one camera! My recommendation is 64 ASA, to have fine enough a grain, then add a flash unit, which I did not carry. I also carried my own newly acquired 26mm-focal-length Minolta camera. The wide angle view of this camera was useful in several cases, where lack of time prohibited changing objectives of the 35 mm camera. Unfortunately, this camera was purchased just 4 days before the earthquake, and the first trial film was still in the camera. This camera malfunctioned and was returned to the store.

An international driver's license would appear quite valuable in some foreign earthquake scenarios. On this occasion it turned out to be unnecessary, since transportation including driver was available.

A very valuable item for any field investigation is a portable tape recorder. I intended to borrow one, but did not, mainly because of the weight and bulk considerations. However, the shirt pocket size recorder now appearing on the market should become very useful.

I left Ottawa 19:25 EST on Friday, 6 February, for Toronto. After an overnight stop there, I flew Air Canada to Miami. Reservations had been obtained on Aviateca, the Guatemalan airline, to arrive in Guatemala shortly after 1500 local time. A long delay due to processing and loading of relief material resulted in arrival after dark, too late to make safe contact with the EERI group. "Safety" refers to the personal safety of a lone traveller in unknown territory with imperfect knowledge of the language and native "mores". It later turned out that the average citizen may be very peaceful,

but there were some reports of marauder gangs, and also of vigilante groups who shot looters on sight. I also talked to the American tourist victim of a knife-point holdup on a busy downtown mall. An interesting observation were the large number of machetes carried, usually wrapped in some newspaper inside the city.

I went to the National Observatory, our rallying point for the afternoon, where I found one native technician-guard, 4 Mexican seismologists and half a dozen calling cards of people that had already passed through the observatory. After spending the night with the Mexican colleagues on the floor of the laboratory, I made contact with the American EERI reconnaissance team on the morning of 8 February and joined them just in time to go on a damage inpsection tour.

Sunday was spent making official inspections for damage of buildings under the jurisdiction of the Department of Public Works. Each team consisted of one or two American or Mexican engineers and two local engineers. I joined the team lead by D. Moran, EERI team leader. We started with a telephone exchange, which later turned out to be the central exchange for all Guatemalan foreign connections and was, therefore, given a second inspection a few days later. Next on the list was the Public Health headquarters, a catholic university, the old U.S. embassy, and finally the equivalent of our "Queensprinters". Detailed engineering descriptions are not the subject of this report, but were made on forms which the Americans had brought with them and suggested for official use and which had been adopted by the Guatemalans. Sunday evening as well as later evenings were filled with exchanges of experience with members of other inspection teams.

Monday I travelled with D. Moran and an official Department of Roads crew to a 30 km distant destroyed bridge; many landslides along the route; one trailer-tractor buried up to the roof, another slide buried an ambulance and trailer during the second large earthquake on Friday. The bridge was apparently the only one of modern construction to fail. Concrete abutments stood without visible damage, but shear keys of rocker-supports of the middle 3 spans had failed so that the bridge deck could move sideways, then drop almost straight down. The bridge was 21 years old and the construction very similar to bridges then built in California. After returning we inspected the building that housed, amongst others, the Canadian Embassy. I had contacted the Canadian Embassy as advised to do by our External Affairs people. The only apparent interest of the chargé d'affaires was to ask us to inspect the premises and help him calm down his personnel. The building had no structural damage, but damage to shear brick walls was quite substantial, and looked dangerous. Despite assurances that the building was structurally sound, the office was not reopened two days later, and iron gates blocked the entrances.

On Tuesday I visited with D. Moran, the headquarters of one of the two power companies to interview an engineer about damages to power generating and distribution plants and equipment; later we visited the only damaged transformer station. All generating stations were situated west and south of the city and there was no damage to generating capacity. Transmission to the city was interupted for about 10 hours. Damage had resulted from failure of several transformer undercarriages, resulting in excessive displacement at the top.

Around noon we attended a meeting at the headquarters of the Public Works Department. By that time, 115 buildings out of 150 under the jurisdiction of this department had been inspected. It was suggested that the local engineers could now finish the job by themselves, possibly with some help of their Mexican colleagues. The EERI engineers were thanked for their help, and this ended their official aid program. EERI is almost committed to return within a few months to hold a seminar of specialists to discuss the kinds of observed building failures and improved methods of construction. Much of the damage to modern buildings was caused by poor or inexperienced detailing, often by poor workmanship. In the afternoon, 4 of our group hired a fixed wing aircraft to fly over the fault area, which had already on Saturday been visited by Dr. Schwartz, a geologist. The fault breakage was clearly visible in many places, but nobody in our (engineering) party would have called it continuous for 140 km. That probably takes a geologist, possibly a helicopter instead of a fixed wing, and more time.

Wednesday I spent on an "unofficial" tour with two engineers to examine some spectacular building failures. Several other buildings were recommended during evening bullsessions, but time was limited. In the afternoon I joined the two EERI geologists; we rented a taxi and drove to Chimaltenango, said by some to be the most heavily damaged area, although there is disagreement. The damage in this provincial capital is pretty total, although I have seen worse and I also have several slides of brick buildings standing in the rubble. This area is well west of the originally recognized fault break, further away from it than Guatemala City, which is about 25 km

perpendicularly from the westerly end of the visible fault trace. I visited the cemetery here to check for tombstone rotations and/or fall direction. However, there are practically no stone monuments as we know them. Instead the Guatemalans build little brick houses for their dead, and these brick buildings survived surprisingly well.

Wednesday evening we all had dinner together; just when I toasted the people and their initiative who had founded EERI in the late 1950's, thanking them for the invitation to join their expedition, the table started moving between us and the windows rattled for a farewell quake.

The EERI group left Thursday morning. I went to the Geographical Institute to purchase some maps, then to the National Observatory to take some more slides and look for other expeditions. Here I met Charles Knudson from the USGS for the first time. He had one seismoscope record containing 2 years of earthquakes. He also had an accelerograph working in the vault of the National Observatory, but the strong shocks of the evening before were not recorded. Equipment malfunction was still suspected. I also met Dr. Fiedler from Venezuela, who arrived this morning. Using a tape recorder, he recorded a mutual interview with Knudson. I gather he intended to visit the President of Guatemala. He seems to be a good PR man. In the afternoon he expected a Venezuelan jeep and instruments with which he wanted to go to Lake Amatitlan, a resort area, to study volcanic aftershock activity. I then joined the Mexican seismologists to look at the results of their aftershock studies, now going on for almost a week. I will discuss their results at a later point.

Finally, I engaged in some PR activity myself. The previous day I had on the spur of the moment agreed to talk to a "few" architects. This arose out of a short conversation with the local engineer of one of the damaged buildings. He had contacted maybe 6 to 8 people, but as the time approached, the lecture hall was crowded and people jammed the doorway. After speaking for about an hour, I answered questions for almost another hour. An interesting hypothesis advanced from the floor was that the earthquake had had something to do with the coldwave, since in 1917/18 it was also unusually cold before or during the earthquake period. I include this detailed account as evidence for the lack of authentic background information available to the population. The danger involved in such public appearances is not so much contradiction between different scientists, but inadvertent emphasis on one or the other aspect, which is then easily quoted out of context. This may have happened, e.g. to Plafker of the USGS, who was several times quoted in the paper, including with such statements as that there cannot be any more earthquakes for another 50 years. This ignores the fact that Guatemala lies in a graben, not dissimilar to the Managua graben, which might not have been active to any great extent during this earthquake.

This terminates the day-to-day account of my visit to Guatemala; I left the country on Friday morning, 13 February.

EERI. The Earthquake Engineering Institute was founded as a private institute in 1949. Originally restricted to persons with significant contributions to earthquake engineering research, membership has recently become available to all interested persons. The primary purpose, as the name implies, was field investigations of earthquake damage to engineering structures. In later years its interests and activities expanded and its mode of operation is described in detail in the Institute's Field Investigation Guides. Basically, after a foreign earthquake of sufficient interest, an initial reconnaissance team is quickly organized by the Institute's president or his designates. Team members travel together to the earthquake scene if possible, preceeded by an experienced advance man. Travel costs seem to be born privately, or by the respective companies of the investigators, and may later be reimbursed. This impromptu arrangement is great for speed, which is so essential for the initial reconnaissance, because much of the evidence is quite fragile and access quickly becomes difficult. Typically, this first reconnaissance team will superficially cover as many aspects of field investigations as possible, documenting the more transient phenomena and identifying subjects and areas for worthwhile follow-up investigations. In this case at least two additional small groups of engineers travelled to Guatemala later in February and it was also suggested that a geologist should be sent to walk along the whole length of the surface rupture. The first reconnaissance team which I met consisted of:

D. (Don) Moran, consulting structural engineer, specialist in earthquake risk reports, now retired, Ventura, the official group leader;

T. (Tom) D. Wosser, Degenkolb & Associates, Consulting Engineers, San Francisco;

W. (Bill) H. Smith, Regional Director, Oakland, Construction Codes and Standards, The American Iron and Steel Institute;

Bob Preece, Testing Engineers, Inc.;

Dr. David Schwartz, geologist, Woodward-Clyde Consultants;

Dr. Raymond Rice, Dames & Moore, San Francisco.

It should be noted that all presented consulting interests apart from being EERI members.

Although D. Moran had come earlier, no official contact had been made by the group until Friday afternoon after the second large shock, when the rest of the team arrived. By this time, Department of Public Works officials had closed down the airport. Informal enquiries at the airport quickly led to contact between the EERI team and the Public Works Department at its highest level. The next morning, Saturday, Public Works organized their own engineers into inspection teams, each under the guidance of a foreign experienced "earthquake engineer". Mexican engineers had in the meantime also arrived, although I do not know their original manner of contact with Public Works. The new "official" status of EERI led to availability of official (free) transportation, also for those members of EERI not directly involved in inspections, but whose direct interest was the identification of the earthquake epicentre and faultline. We

received official letters of accreditation which in many cases helped to gain passage to otherwise inaccessible areas and in general gave the bearer some measure of officiality. Official transport was of course scarce, moreover we made it quite clear that we would in no case accept helicopter support, if this were withdrawn from emergency operations. The Vice-Minister of Public Works himself travelled on Tuesday in a Mexican helicopter, and seeing this we did not wait for him to come through on his promise of a helicopter for us. Instead, we rented a private aircraft in one case and obtained free support from a private aircraft owner in another case.

The results of the field investigation will eventually be published, similar to the sequence of papers in BSSA, August 74, on the Managua earthquake. EERI at the present time tries to act as a clearing house for preliminary reports. The leader of the first reconnaissance party, D. Moran, collected copies of all damage reports and other individual contributions, and has presumably by now submitted his report to EERI headquarters. Since I did not follow independent investigations on this occasion I do not plan to report to EERI, but have asked to be placed on the mailing list and offered to contribute if they consider this worthwhile.

Other Teams. EERI had not sent the only surveillance team. Charles Knudson of the U.S. Geological Survey left San Francisco on Thursday to check the strong motion instruments. Other members of the independent USGS team were Karl Steinbrugge, Alvoro Espinoza, Raul Husid and George Plafker who all arrived on Friday. Their team worked much more loosely than EERI and on more diverse aspects. Ch. Knudson's task is mentioned above. K. Steinbrugge, who, I believe, is chairman of the Architectural School at Berkley, spent all his time with EERI, and I only accidently learned of his "official" association. Plafker is a geologist, and occassionally associated with the EERI geologists. Finally, Espinoza and Husid are native Spanish speakers and attempted isoseismal surveys in the city. Although they lived in the same house as we did I only saw them once and do not know how successful they were.

A two-man team from the University of Galveston, Texas, T. Matumoto and G. Latham also lived in our pension. They kept to themselves, had a few seismometers in the vicinity and left after only a few days.

At least two different institutions from Mexico had scientists there. I contacted only one group, who were stationed at the observatory, running smokers and calculating aftershock epicentres. Again, there was no sign of communication between them and EERI on any level.

On day eight, Fiedler from Venezuela arrived with 4 seismometers and one jeep. Listening to him, I got the impression that he had connections at the highest level, i.e. President Laugerud himself. Fiedler brought one young civil engineer with him.

THE EARTHQUAKE AND ITS SETTING

The earthquake struck Guatemala at 09:01:46.0 GMT, Wednesday, 4 February, 1976.

The National Earthquake Information Service (NEIS) at Boulder gave as the formal epicentre location 15.27°N, 89.25°W, halfway between the towns of Gualan and Los Amates in the Motagua Valley, about 160 km northeast of Guatemala City. From there it propagated bi-laterally, with the final surface rupture forming a gentle arc about 240 km length as shown in the accompanying map. The NEIS Richter magnitude is 7.5, while U.C. Berkeley estimated 8.0. Fiedler, from Venezuelan records, initially estimated m_b 5.6, then went up to m_b 6.1. Canadian short period records showed a 13 station average of m_b 5.6 within 10 seconds after the onset, while after 50-70 seconds the average increased to its maximum of about m_b 6.2.

The earthquake occurred along the Motagua fault zone, which together with the more northerly Polochic fault zone represent the landward extension of the Cayman trough, currently comprising the boundary between the North America and Caribbean Plates. The Motagua zone is an old structural feature that may have formed originally by plate collision in the Lower Cretaceous (110 million years) and transcurrent left lateral movement appears to have been initiated 55 million years ago together with the opening of the Cayman trough. (D. Schwartz, private communication).

FIELD SURVEYS

These sections describe in approximate order of interest and importance the various projects and activities observed during the week. In some I was involved, others I observed more-or-less distinctly, others again I know only from hearsay. I will differentiate between them when necessary.

Geological Investigations. Schwartz and Rice from EERI visited the fault area within one day of their arrival by fixed wing aircraft. Later excursions were made by helicopter, allowing better observation and landing for detailed investigations. There was loose cooperation with Plafker. Later reconnaissance trips were made closer to the city to look for secondary faulting. The surface faulting associated with the earthquake extends almost continuously for 240 km in a gentle arc from the vicinity of Mixco Viejo, northwest of Guatemala City to Los Aminas, about 220 km northeast of Guatemala City; the closest approach to the Capital is 23 km to the north. An apparent minimum of displacement of about 40 cm is observed near the epicentre, with displacements increasing towards the west, with 1.4 m left slip in the town of Churrancho north of Guatemala City reported by Plafker. A vertical component of slip is absent. A secondary fault was observed for a short distance 0.5 km south of the main trace and some secondary faulting appears to have occurred along the Mixco fault, west of Guatemala City. Major landsliding was observed to the north, northeast and northwest of Guatemala City. No direct evidence of liquifaction was observed in Guatemala City, which is situated in a graben filled with loosely cemented tuff and other volcanic material,

straddling the continental divide at an altitude of about 1500 m.

During the current dry season, the surface faulting will be recognized for some time, but when the rain starts in May, it will disappear very quickly. Before that time USGS hopes to send a geologist to walk the whole length of the fault. Finding the trace in a country like Guatemala is not very difficult, the area is currently arid, and only sparsely covered with vegetation. Still, there were arguments between the geologists and the engineering observers as to the length and continuity of the surface break. However, Schwartz had done considerable mapping of the area a few years ago. He knew the position of the active fault, which was much further south than expected on the basis of a geographic map. On a series of pre-quake air photos, Schwartz picked with great accuracy the most recent line of activity, which agreed with later air observation.

When discussing the different earthquake mechanisms in eastern North America, Schwartz's opinion was that surface breaks in the east are unknown mainly because nobody has looked for them. His recommendation is always to bok for surface breakage for about magnitude 6 and up.

Aftershocks. Only two teams were recording aftershocks during my week there. Contrary to my original impression, the USGS had not brought any additional instruments in. Peter Ward from USGS has a permanent small array of telemetered stations centered around Guatemala City; it is mainly designed to observe volcanic activity. It is recording on helicorders, the paper is changed by a local technician, but no regular readings seem to be made. The array is

30-50 km in diameter and should give good aftershock locations at the west end of the main shock zone. Peter Ward did not come to Guatemala while I was there.

There were 5 or 6 Mexican scientists in the city, I think mainly from the University in Enseñada, but some ~~whom~~ of those I did not meet seemed to be from the National Autonomous University. Lomnitz attended a Paris UNESCO meeting, which he unsuccessfuly tried to have postponed. The Mexicans had at least 4 smokers running and had located 13 aftershocks by Thursday, 12 February. They had set up their instruments east and south-east of the city, in directions with no or little road blockage, in a way complementing the 6-station permanent array. The aftershocks which they had located followed the western part of the observed surface fault breakage but then continued further west, where they then seemed to bifurcate NW and SW, running towards the volcanic chain, approximately along the Mixco fault. Since the Mexicans obviously concentrated on the larger recorded shocks, this areal distribution is subjective and does not mean that there was no energy released further east.

Matumoto and Latham recorded aftershocks with a few (3?) instruments until the 9th or 10th. I did not see any results. They might give some at the SSA meeting in Edmonton where they have scheduled a paper on Central America. Finally, G. Fiedler from Venezuela had instruments and a jeep arriving late on the 13th; he wanted to concentrate on volcanic shocks and planned to set up SSW of the city.

A week later a Charlie Langer from USGS was supposedly down also measuring aftershocks.

In general it appears to me that the aftershocks are not delineating the main shock area, but occur at other known areas of activity. For instance, the largest (mb 5 3/4 - 6) aftershock epicentre on Friday, 6 February, 18:19 GMT, is given by NEIS as 14.3°N and 90.5°W (preliminary) just southeast but very near to the city. I plotted historical seismicity and found a strong concentration of events at this location. They are mostly deep events and presumably connected with the descending Cocos plate.

We felt aftershocks almost every night and a few during the day, especially in the beginning. This does not necessarily reflect a decreasing activity, as one gets very quickly used to these disturbances and sleeps through them. Typically, I would wake up for an unknown reason, or from very light shaking. The shaking would then intensify for a few seconds, and pass (P-S-Lg-roll?). Duration hardly 10 sec. Some people reported dogs barking before feeling any shaking. I believe this to be a simple matter of waking threshold. More about this later.

Strong Motion. No accelerograms were obtained either of the main shock or of the first week's strong aftershocks. Knudsen of USGS was in charge of strong motion instrumentation but the equipment belonged to Guatemalan authorities. Knudsen was down for a service trip last July and had not encountered problems. At the time of the main shock one instrument was out of paper, then a battery failed, finally it did not trigger. Whatever it really was, Knudsen said on day eight: "Sure we have a seismoscope record, just discovered it yesterday, worked hard on it to bring it out, it has the past two years of ground motion on it." Thus, strong ground motion parameters will remain speculative.

During our building damage survey in the city, Don Moran allowed 10% g maximum. Mushroomed concrete structures with heavy roofs and undetermined column strengths are of little use. Overturned simple objects in high buildings only reflect building amplification. I went to a cemetary to look for motion of monuments, i.e. simple geometric objects, but since the Latin way of burial is different, this was a failure. They store their dead in little brick buildings, mausoleums, which generally survived the quake much better than the adobe buildings for the living. My only conscious effort of estimating maximum acceleration led to a vague 15 to 25% at an unspecified frequency, based on a cleanly fallen flower pot, towards the east. Most unconstrained failures which I observed were towards the east. This suggests ground motion to the west, which is contrary to what one might expect on the south side of this left-lateral fault.

Isoseismals - Intensity. In addition to general damage inspection, isoseismal surveys require considerable information exchange with the populace. Language difficulties can be severe, especially if one is trying to communicate with the less educated. In Guatemala, two people tried to cover the city, both were native Spanish speakers, Husid from Chile, and Espinoza. This is not enough manpower for the large damage area of this earthquake, but I seriously doubt the value of the survey in any case. Even to the casual observer, damage was much more correlated with prevailing construction type and with topography than with proximity to the fault. Relevant observations, not necessarily my

n, are the following: Near the ground-observed fault line almost total destruction of adobe buildings prevailed, but at distances only of the order of 100 m, blocks of the same building type were standing. About 5-10 m from the fault trace a transformer building survived without visible damage. Rows of wooden-post, thatched-roof houses survived twisted but standing right on the fault trace. Generally, there were not too many modern buildings near the fault. It is difficult to place adobe damage on the intensity scale: is it masonry D or worse? There were quite a few railroad bridges along the fault without apparent damage. However, a 5-span 20 year old highway bridge lost 3 spans: poorly secured, they slid sideways on the rockerbearings and dropped straight down. The welds along the ıear keys which were supposed to prevent this, were about 6 cm x 2 cm maximum, two sides, two bearings at each end of every span, about 100 cm^2 per span, maybe only 50 cm^2. Permissible stress is of the order of 1000 bar, safety factors of about 2-5 for steel, therefore failure maybe near 4 k bar. Estimating 1 kiloton per bridge span (50m x ½m x 10m x 3) one gets, without error bars, acceleration of approximately 4% g, to which the friction would have to be added, but the amplification of the tall abutments divided out. A rather useless guess!

Within Guatemala City, the greatest damage was towards the north where the fault was; however, not only were the poorly built adobe buildings again the hardest hit, but especially those along the very steep valleys cut into the loose volcanic tuff and sand. Outside the city, the hardest hit areas were generally said to be those to the west

and to the northwest of the western termination of the observed surface fault breakage. Later an extension of the fault trace in this area was found. However, these areas are high-lying districts, the so-called altiplano, mainly inhabited by the Indians, again living in very poorly constructed buildings. I went to the capital of Chimaltenango, said to be 95% flattened - although my estimate is lower - from where I brought many photos of brick buildings still standing. It is of course not impossible that the higher elevations suffered some amplification effect. This was clearly observable along the ridges where damage on top of the ridges was almost always greater than the lower-lying areas. An alternative suggestion is that the energy release was larger west of the well-visible trace, as perhaps indicated by the aftershocks, which seem to deviate precisely into this area from their more linear concentration further east; also as pointed out earlier close to the epicentre there was minimum displacement of approximately 40 cm while at the west end it just about reached its maximum.

One final observation, quoted from an unknown observer: damage north of the fault was generally much less than at equal distances south. The explanation may be the more competent soil on the northside. Ted Irving tells me that southern Mexico can almost be considered a Grenvillean type of shield area. This would be the southern edge of the North American plate, just north of the present earthquake zone, although I think it is really not as simple as this.

In an earlier section I gave some estimate of maximum acceleration from overturned objects. I only caught on to such observations after a while on my own, the apprenticeship with the Californian earthquake

ecialists was no help. With them we discussed intensity estimates as required on the inspection forms. On the first day, third building, I objected to their estimate of intensity of VI and got quick consensus for VII, simply by discussing the definitions of masonry classes. During the aftershocks we had more arguments about duration, intensity and direction. I determined the direction of motion of an earthquake during the first night by placing my compass on the bed. It was ESE, but I cannot tell which phase it was nor give a good estimate of the duration. Upon awakening, perception of time is very poor as evidenced by well-known pre-waking dreams. Thus anything between 2 and 10 seconds is my estimate for a typical nightly aftershock. Other people agreed on this time, not very difficult with an error factor of 5!, but put he direction of motion at right angles to mine. Estimates of intensity for these aftershocks were up to IV, but in the light of all I said I would prefer not to quote intensity and let an experienced "seismologist" make a suggestion.

Engineering and Technical Studies. These topics are basically not the concern of our Division, however, we should try to interact with engineers to a certain extent. For instance, our isoseismal studies are closely related to engineering damage surveys with a shift of emphasis from modern, carefully designed structures to more conventionally or traditionally built common structures. In judging the latter type of damage for purposes of intensity estimation, we can probably learn from engineers things like differentiation between one knocked-downed chimney and another one.

Other areas of technical studies will only be of peripheral interest to us, but affect our operations strongly. For instance telephone communications will almost definitely be poor. If exchanges or lines are not destroyed or badly damaged, they may temporarily be closed until inspected for safety. If working, they are likely to be overloaded. Power supplies for an urban area may be knocked out completely or partially, again affecting communication or operation of some of our field equipment. However, generalizations are of no help, except as basis for discussion, and conditions will always have to be judged on their relative merits.

PUBLIC RELATIONS

This aspect was not well handled, possibly because Guatemala does not have full-time seismologists. The Director of the National Observatory is a meteorologist. Although he has a considerable number of staff, only one man showed some seismological knowledge and skill. He was described as a technician, responsible for changing records. The observatory has 2 permanent instruments, Wiecherts, recording 2 horizontal and 1 vertical component on smoked paper with low magnification, which the technician did not know. In addition, USGS has a small array of telemetered stations centered around Guatemala City, mainly designed to observe volcanic activity.

The lack of national sources obviously led local news media to search out other sources of information, which were not necessarily as well coordinated and consistent as we would like them to be in Canada. To start with, the National Observatory placed the main shock about 50 km (or miles?) SW of the city. This was quoted even in the Ottawa newspaper. In view of the 6 station visual displays sitting in the main hall of the Observatory, this is hard to understand. Eyeballing with a ruler and protractor gave me an epicentre on an azimuth of about 70°, but many days after the quake the papers still talked about a W-SW'ly epicentre and marvelled about the fact that there was no damage in that direction. I can only explain this by assuming that nobody at the Observatory made a real effort to clear up this misunderstanding. On Saturday night after the quake I saw a piece of paper in the vault with very reasonable coordinates scribbled on it. So somebody in the

observatory knew, but the lines to the press were not established. Correct epicentre information and mechanism appeared in the papers as early as Saturday, but were connected with USGS, often with Plafker. Unfortunately, he was also occasionaly (mis)quoted as having said that such an earthquake could not again occur within another 50 years. Throughout the week, many aftershocks occurred, and the National Observatory issued cumulative counts and gave Mercalli intensities for the bigger shocks in tenths of a unit. I did not find out who and how these were produced, but there was a clear differentiation between Richter magnitude, given by the USGS people and Mercalli numbers which were always associated with the National Observatory. I think this was a simple but harmless way of giving a numerical indication of the amplitude of the low-sensitivity smoke-recording Wiechert at the observatory.

Many people slept in tents even though their houses' survived the main shock unscathed. Statements on probability of aftershocks were critical to them and oversimplification of the situation as in the above misquote of Plafker could be lethal to many. In fact, because in 1917/18 the second shock was the more severe, people were in general inclined to assume the worst and stayed in their tents.

The foreshocks are a much more interesting question. There were at least 2 fair-sized foreshocks a few days before the disaster. The Observatory technician pointed them out to me as noteworthy, maybe suspicious. In an environment so obviously seismic as Guatemala, two or more shocks would not be taken seriously, but had an on-line epicentre

determination program existed and possibly some mechanism-differentiation, I wonder if some warning could not have been given. We should eventually hear more about this. I believe, Lomnitz is currently developing a large on-line system, which he calls Resmac, in Mexico, and wants to extend it into Central America.

A few weeks after the quake the Guatemala newspaper El Tiempo claimed that American underground nuclear tests in Nevada had triggered this earthquake as well as others in Central and South America. Such statements are most likely politically inspired and even a good public relation activity of a seismological agency might not be able to stop such statements. In fact, this news item was printed as factual in a French Canadian paper, without checking with some authority.

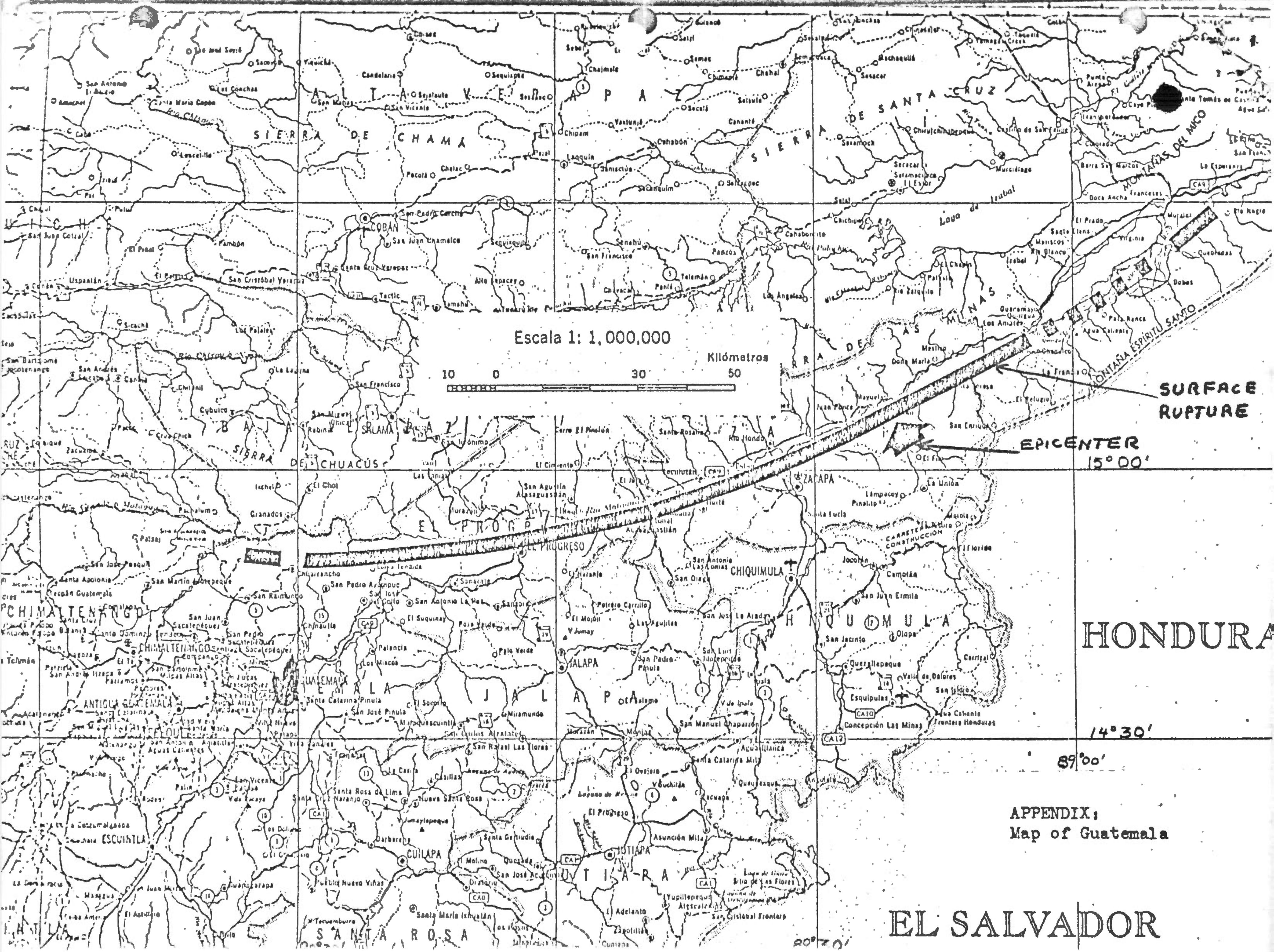
CONCLUSIONS

The Guatemala observation visit was undeniably a very useful, personal experience for myself, although one could argue that whatever experience I gained and have been able to communicate to colleagues in the Division, could be found in the literature, with an equal or smaller investment in time. In terms of training value, practical experience can never be replaced by academic knowledge in an emergency case. This recognition was probably the basic reason for the study groups' recommendation of such an observer visit. However, it had never been quite clear what target areas or countries we should aim for, since there were doubts about the applicability of foreign experience for a Canadian earthquake scene. Apart from language problems, social structure, customs and construction types are so different as to throw genuine doubt on the value of earthquake reconnaissance trips outside this continent. I was lucky enough to remember enough Spanish to feel fairly at home after a few days, but the thought of an independent mission or even only an observer mission in Tokyo or Turkey is not attractive. Guatemala was near enough to home base to keep the fare within reason; the earthquake was definitely big enough; and finally the complexities of damage patterns in the near source region were such as to bring this earthquake very definitely in the class recommended for action by the Study Group. Similar events may again be useful for training of other staff members, but my recommendation is to focus

future attention on the coterminous United States.

During this visit I remained in close liasion with the EERI team. This allowed me to cover considerable ground in a short time at reasonable cost, which I could never have done travelling singly. However, despite recent diversification, EERI is still a consultant oriented organization, concentrating therefore very much on damage to modern structures, their foundations and sub-soils. Our divisional mission is sufficiently different, so that I would in future missions recommend to work more independently. Liasion with EERI is useful to the extent of regular evening meetings for exchange of experience, information and possibly for coordination of efforts.

Another point bearing repeated emphasis is the need for quick action. Although this is obvious for the deployment of aftershock and additional strong motion instrumentation, it is equally important for most other investigations. Not only will clean-up operations quickly diffuse or dissipate important evidence and change factual observations of witnesses into "stories", but access to damage becomes more difficult within days and the patience and initial cooperation of the populace with "curious researchers", not offering material aid, disappear. In this connection, official identification and close cooperation with emergency agencies is important and we must continue to foster our relations with Emergency Planning Canada and its sub-agencies in certain critical regions. In case of doubt about the value and the scale of a post-earthquake survey, I would therefore recommend always to send a one or two-man reconnaissance party immediately.



APPENDIX:
Map of Guatemala