Instituto Panamericano de Geografia y Historia

Final Report

Seismic Hazard in Latin America and the Caribbean

Volume 1

Project Catalogue and Seismic Hazard Maps

By

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Foreword

The original proposal for this project was put together at a workshop held in México at the secretariat of IPGH during the summer of 1989. Present at the meeting were Sylvain Dufour of IDRC, Dr. Gerardo Suárez from México (UNAM), Dr. Aristóteles Vergara from Central America (CEPREDENAC), Ing. Alberto Giesecke from South America (CERESIS), Dr. John B. Shepherd from the Caribbean (SRU/UWI) and J.G. Tanner and Ing. Leopoldo Rodríguez (Secretary General) of IPGH[1]. Those of us from out of town were staying at the Hotel Emporio in the centre of México City

The first morning we met after breakfast in the coffee shop of the hotel just prior to leaving for the offices of IPGH. While we were enjoying a coffee, the city was struck by a large earthquake (about magnitude 7) which occurred a couple of hundred kilometres to the southwest of the city The group moved quickly to an archway to wait out the earthquake The motion lasted for nearly thirty seconds, near the end of which loud cracking noises could be heard from the upper part of the building, giving the impression that if the shaking continued there would likely be damage to the building. Fortunately, the movements ceased at that point as did the pandemonium in the coffee shop.

After the earthquake the streets were full of people, many of whom had scurried there during and after the earthquake. There was no significant damage to any of the buildings in the vicinity of the hotel and we felt fortunate to get off with only a severe shaking. While perhaps a more normal experience for the residents of the city, the event was unsettling to those of us not accustomed to the effects of large earthquakes on México city. Two of us took note of the magnitude of the motion of the building and agreed afterward that it was about two feet peak to peak.

This rather auspicious start to what eventually became an approved project of IDRC set the tone for this study of seismic hazard in Latin America and the Caribbean. The frightening nature of the experience was a sharp reminder of the possible ravages of earthquakes and emphasized to us one aspect of a damaging earthquake that seems so often forgotten - that of the emotional trauma particularly in the case where there are personal losses or injury to family members and/or close friends In its own way, this experience possibly contributed to the decision by some of the participants to undertake this study (a study that will continue beyond the life of this project) of the effects of earthquakes through recorded time on the social and economic life of the citizens of their respective regions.

Those of us from countries where the tectonics are much quieter have little comprehension of the devastation suffered by the citizens of any area due to a damaging earthquake, to say nothing of the trauma associated with other geological hazards such as volcanoes. We are, however, frequently asked to help out in the event of disasters caused by earthquakes by providing emergency relief and perhaps equally importantly, funds and expertise to assist in the development of technical activities designed to provide improved monitoring of earthquakes or volcanoes. This latter is an important contribution, but much more lasting if accompanied by longer term efforts to

[1] See the first page of the Introduction which follows immediately for an explanation of these acronyms.

quantify the hazard using the talents of the local specialists throughout the region. This project is one such effort in this direction, but as successful as it has been we should remember that it is a start only Further studies should follow to extend our understanding to the effect of soils on seismic waves for example and to develop wherever possible a similar capability in the case of other geological hazards.

Finally, this project proved far more complex and time-consuming than originally estimated. Many long hours were spent at the computer by all involved in a concentrated effort to produce a product, consistent with conventional international standards, that meets the needs of the local constituencies. No doubt at least some of us were spurred on by the experience in México

Introduction

The vastness of the project area and the attendant number of individuals and institutions concerned with seismicity and seismic hazard dictated a style of operation that was regional in character Four organizations (see below), in addition to the Instituto Panamericano de Geografia y Historia (IPGH or PAIGH), formed the core of the project and in turn each was responsible for contacts with agencies and individuals from within their respective regions. Contacts involving local agencies and individuals is a *sine qua non* for any successful project in Latin America and the Caribbean - local authorities will always look to the local experts for advice and they in turn will seek information at the regional or continental level to place their advice in context.

The organizations involved in the project are:

- Universidad Nacional Autónoma de México - UNAM - located in México City,
- Centro de Coodinación para la Prevención de Desastres Naturales en América Central - CEPREDENAC - headquarters in Guatemala,
- Centro Regional de Sismologia para América del Sur - CERESIS - headquarters in Lima, Perú,
- The Seismic Research Unit of the University of the West Indies - SRU/UWI - located in St Augustine, Trinidad.

Originally the contact from CEPREDENAC was its Secretary General, but subsequently this responsibility was transferred to the Director of the Escuela Centroamericana de Geologia of the Universidad de Costa Rica - ECG/UCR - located in San José, Costa Rica - where it has remained for the last four years of the project.

The project was overseen by a Steering Committee composed the Project Leader of IPGH and individuals nominated by the adhering agency. The meetings were entirely open and representatives of related projects and organizations from outside the area were invited to attend its meetings without vote. This Steering Committee met about once per year contemporaneously with a technical workshop which consisted of presentations on topics of current interest to the project. This connection with the technical activities helped the Steering Committee simplify its discussions and avoid the possibility of taking the wrong route for any activity.

Given this simplified management structure with its strong connections to the technical activities, the project proceeded iin a straightforward manner despite problems with maintaining its original schedule. Indeed, one such delay forced the Project Leader to take a much more active role than originally foreseen to overcome the loss of almost a year of technical activity at the project level.

The project also proved to be much more complex than originally forecast. We had to allow additional time at the local level to complete and approve both the local and regional catalogues and seismic hazard (ground motion) estimates. Any effort to jump these hurdles would have led

inevitably to reduced quality of the outputs, undoubtedly to major dissatisfaction at the local level and possibly to compromise of the outputs of the project

Within the limitations imposed by the above a two phase project, first the catalogue and then the hazard estimates, unfolded which unfailingly started with the fundamental work at the local level followed by the regional and project level actions. Under this regime any early delays at the project level were quickly overcome. Research time was also spent on such things as software and the method of conversion to moment magnitudes, the magnitudes computed by local seismologists and compiling information available from global centres such as the ISC and NEIS, all of which proved to be of enormous benefit. Although the catalogue took by far the longest time at both the project and regional level, the results appear to justify the extra effort.

By the time the hazard calculations were completed, the official end of the project had been reached and the final phase, writing up and presenting the results to the community, was underway. At this point, however, renewed activity, after a century of quiet, at the Soufrière Hills volcano in Montserrat led to delays as one of the authors of this report (JBS) spent about two years travelling back and forth from the UK to Montserrat. This situation was not entirely bad as favourable publicity accrued to the project through the excellent work of Dr. Shepherd

The only major deviation from the plan originally set up by the Steering Committee concerned secondary catalogues, such as an index of publications, a compilation of first motion results, an index of strong motion recordings and other such quantities that relate to a compendium of epicentres and magnitudes for earthquakes. Of these only the bibliographies were carried out at the project level. This departure was not due to time limitations, but rather the view of the Steering Committee that activities at the project level should compliment and not replace those at the local and regional levels. Put simply, the compilation of these additional catalogues was seen as too much a duplicative effort and therefore abandoned. The bibliographies on the other hand were regarded as the key to directing individuals to the proper local experts and therefore were pursued at the project level.

The bibliography was approached from six perspectives. These were respectively a bibliography of publications produced by the participants in the project (Appendix I), bibliographies relating to the earthquake catalogues of each of the four regions (Appendices II through V) and a generalized bibliography of seismic hazard on a global scale (Appendix VI). In the case of Appendices II to V, the bibliographies were limited to providing a key for interested students to pursue seismicity studies in the particular region in greater detail. The same may be said of Appendix VI which is intended only as an overview of global efforts.

The Steering Committee actively encouraged all participants to publish their results as soon as possible with the result that there is an extensive list of contributions from the project. To aid the process of dissemination of information, the project published several technical reports which consisted of mainly presentations made at the annual workshops. These compilations also served to fulfil the requirement of IDRC for annual reports. The bibliography of contributions from the project is given in Appendix I.

In this report the project catalogue and associated software are presented first followed by a discussion of the hazard calculations complete with a presentation of the methodology and software. Finally the maps computed at the project level are presented and discussed in the context of the results obtained by each of the regions and the procedures laid down by the Steering Committee. Basically, each region was responsible for the computation and the approval of its hazard maps and the writing of the report to accompany the map. At the project level, the Steering Committee directed that we compute a reference map using a method specially developed for this purpose This map would serve as a means of comparing seismic hazard in one area to that in another.

In the remainder of this introduction, the main results of the meetings of the Steering Committee are presented briefly to relate the activities of this body to the progress with the project and to provide some background understanding of why activities were undertaken in the manner described.

Meetings of the Steering Committee

Seven meetings of the Steering Committee took place over the life of the project which, except for the first, were accompanied by a technical workshop to provide a forum for discussion of current problems These meetings took place at the following times and locations:

- London, Ont , Canada - June, 1990
- Panamá, Republica de Panamá, February, 1991
- Melbourne, Florida, March-April, 1992
- Melbourne, Florida, March, 1993
- Brasilia, Brasil, August, 1994
- Melbourne, Florida, December, 1994
- Melbourne, Florida, May, 1995

Each of these meetings typically lasted a week with a technical workshop on the topics of the day preceding the meeting of the Steering Committee, which usually took place an the last day The Steering Committee made a number of important decisions which are summarized briefly here without comment.

(i) The meetings of the Steering Committee would be working meetings in the sense that the project office was required to provide computing power adequate to test ideas and hypotheses under consideration.

(ii) All outputs at the project level would complement and not replace local and regional results because the project wished to emphasize the importance of local activities.

(iii) The project catalogue would also give preference to local and regional solutions to earthquake occurrences over those obtained from central sources such as the International Seismological Centre and the US Geological Survey

(iv) Originally the Steering Committee recommended the use of M_s as the magnitude to be used for the hazard calculations at the project level, but this was subsequently modified to the use of M_w to be consistent with the Global Seismic Hazard Project (GSHAP)

(v) The project could not meet all of the specifications of the GSHAP project, but cooperated in every way possible within the time available.

(vi) Each region would be responsible for producing a seismic hazard map using a method of its choice and the project (IPGH) would be compile a five level seismic hazard map to serve as a link among the regional maps - the five levels were defined as follows:

- 0 to 62.5 gal (cm/s^2) - minor hazard level
- 62.5 to 125 gal - low hazard level
- 125 to 250 gal - moderate hazard level
- 250 to 500 gal - significant hazard level
- Greater than 500 gal - high hazard level

(vii) México, Central America and South America decided to compute their maps by the source zone method and the Caribbean by both the source zone and historic parametric methods - IPGH would use a version of the historical parametric method developed specially for the project

(viii) Each region and IPGH would produce a final report of no more than 100 pages which IPGH would reproduce for distribution.

(ix) Supported the effort of the Caribbean to establish a region-wide seismology group for the purpose of exchanging information, compiling a regional catalogue, etc..

(x) At the request of the International Development Research Centre in Ottawa, Canada, approved a new project proposal that contained several elements related to seismic hazard and submitted it to the project officer of IDRC who originally indicated that he would attempt to broker it among other agencies in the business of providing aid to developing regions Unfortunately we lost our friend in court through promotion and this effort has fallen by the wayside.

(xi) Adopted a policy throughout the life of the project of encouraging timely publication of results and cooperation with other projects where feasible.

Membership of the Steering Committee.

At the beginning of the project the membership was:

J.G. Tanner - IPGH,

J.B. Shepherd - Caribbean - SRU/UWI,

G.Suárez - México - UNAM,

A. Vergara - Central America - CEPREDENAC,

A. Giesecke - South America - CERESIS.

As might be expected changes took place over the five year interval of the project and at its conclusion the Steering Committee membership was:

J.G. Tanner - IPGH - Project Leader

J.B. Shepherd - special adviser for the Caribbean and to IPGH

R. Zúñiga - UNAM

W. Montero - ECG/UCR (Central America - CEPREDENAC)

A. Giesecke - CERESIS

L. Lynch - SRU/UWI

Acknowledgements

First and foremost we must acknowledge the efforts of all the seismologists and technicians involved with ongoing recording and evaluation of seismic records to produce the basic data for the project and regional catalogues for those events that have occurred since about 1900. As subsequent text will establish, their work has been of uniformly high quality throughout the project area and enabled us to produce a reliable catalogue using moment magnitudes to describe the size of the particular event. While we could not possibly cite them individually or their institutional affiliations, their work is the one of the most important contributions to the project

catalogue. The Steering Committee is profoundly grateful to these individuals and to their institutions for sharing with us the results of decades of labour.

In a similar vein we must acknowledge the efforts of all those involved in compiling historical information on earthquakes and in interpreting these archival records to produce the entries in our catalogues The interpretation of this information is always equivocal, but this in no way should detract from the splendid effort of the individuals and institutions concerned. Again, nearly all institutions in the project area have contributed and again we are grateful for their willingness tor share their results with the project and the international community.

The Secretary General of IPGH has been a constant supporter of the project and has lent the support of his office to the achievement of the goals of the project His enthusiasm and positive outlook have been an asset to the project from its inception. No acknowledgement could be complete without complementing the work of the staff of the Secretary General's office of IPGH. The project leader, who spent nearly six months in México on the project, is particularly grateful for the help of the staff of the Institute in the many phases of the project, despite its being an addition to their regular responsibilities. Their cheerful and positive attitude contributed enormously to what turned out to be a very pleasant, enjoyable and productive assignment.

The project leader must also acknowledge the enormous contribution of UNAM to his stay in México. The Instituto de Geofisica generously recommended to the university that he be granted a visiting fellowship and provided access to all the facilities of the university, including a "cubiculo" vacated by their representative on the Steering Committee while on sabbatical. The professional and technical staff of this large and well regarded institute were to a person supportive of this work and helpful whenever required Without doubt the stay in México was made much more pleasant and productive by the contribution of this institution and its staff.

The project officers of IDRC are all thanked for their flexibility in dealing with unusual situations which always seemed to arise in this project which, as previously mentioned, proved far more complex and difficult than forecast at its outset Had we been forced to proceed along the lines originally laid out in the original budget, the outcome could not have been achieved to say nothing of the effect on the quality of the outputs. The cooperation of the officers concerned was a major factor in minimizing the normal tensions associated with a project which set out a comprehensive and ambitious set of goals with relatively modest funding

The project leader would also like to thank both the patience and contributions of his wife, Patricia, to the project. She tolerated the use of what seemed to be an ever increasing percentage of the house for the project and, of course, contributed her many skills in office management, writing and editing of documents, organizing workshops and meetings of the Steering Committee and generally assisting the project in any way she could. She did so from the outset to the final stages of the project when she was forced to limit her involvement because she took on another job.

The project leader would like to acknowledge the enormous contributions of the members of the Steering Committee to the project Their friendship, unfailing good spirits and positive attitude

despite constant "hounding" by the project leader were prime factors in the success of the project. The efforts of Dr. John Shepherd, the representative of the Caribbean initially, but later a special advisor to the project, deserve special mention because they were an enormous influence in achieving the goals of the project. His knowledge of seismicity in the project area is unique and provided the technical basis for many of the judgements necessary in the compilation of the project catalogue, without which, it may be added, the quality of the catalogue would have suffered enormously. The project leader, while not a seismologist, learned an enormous amount about this fascinating science directly through the contributions of Dr. John Shepherd

Finally, we would like to acknowledge the contributions of Prof Lalu Mansinha of the Earth Sciences Department of the University of Western Ontario, Mr Peter Basham of the Geological Survey of Canada and Dr. Kaye Shedlock of the United States Geological Survey. Prof. Mansinha attended several of the workshops and Steering Committee meetings and contributed many valuable comments to these meetings. He also served as an outside reviewer of the project along with Peter Basham and kindly reviewed the final report.. Peter Basham was also the contact with the Global Seismic Hazard Project (GSHAP) and provided much valuable advice during the course of our many contacts throughout the life of the project, including a review of the final report. Dr. Shedlock is particularly thanked for a very thorough editorial and technical review of the penultimate version of this report

Organization of final reports

As indicated on the title page this is Volume I of what is intended as a series of reports comprising five volumes, each of which will be bound separately and available through the Secretary General of IPGH. The other volumes are respectively:

Volume (Capitulo) II - México
Volume (Capitulo) III - América Central
Volume (Capitulo) IV - América del Sur
Volume (Capitulo) V - Caribbean (El Caribe)

At the time of writing of this volume (Volume I), the reports for México, América Central and América del Sur are in hand and will be printed at the same time as Volume I We have no estimate of the time of availability of the report from the Caribbean.