INSTITUTO PANAMERICANO DE GEOGRAFIA E HISTORIA

Organismo Especializado de la Organización de los Estados Americanos

Peligro Sísmico en Latinoamérica y el Caribe.
Seismic Hazard in Latin America and the Caribbean

Capítulo 2: MÉXICO

REPORTE FINAL

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Proyecto: Peligro Sísmico en Latinoamérica y el Caribe. Seismic Hazard in Latin-America and the Caribbean Project

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Resúmen

En este informe se presentan los resultados del Proyecto de Peligro Sísmico en Latinoamérica y el Caribe, para el área de México. Se discuten las metodologías empleadas en la recopilación de los datos que conforman el catálogo de sismicidad, tanto en su parte histórica como en lo que corresponde a sismos instrumentados. En relación a los datos históricos, se hace énfasis en la búsqueda de información relacionada a la época colonial y precortesiana, efectuada en el Archivo General de Indias en Sevilla, España. A continuación se presenta una regionalización sismotectónica general de México, con base en los datos de los catálogos e información adicional. Posteriormente se presentan las bases para los cálculos de peligro sísmico, incluyendo las relaciones de atenuación utilizadas y la regionalización de fuentes sísmicas para este efecto. Finalmente se presentan los resultados del cálculo de peligro en forma de curvas de iso-aceleración máxima del terreno para período de recurrencia de 500 años.

Summary

The Seismic Hazard Project was born from the need to produce comprehensive and homogeneous seismic hazard maps for Latin America and the Caribbean which could be used by various agencies and other interested parties involved in seismic risk evaluations in these regions. Until now, no such maps were available for most of the regions included in the project or else have been compiled in a non-standard and incomplete form. In the case of México, even though seismic hazard maps existed, they had been based upon seismic information available to the late 1980s which had been compiled in a non-systematic fashion and has thus lacked detail.

As a first step towards the above mentioned objective, the Geophysics Commission of the Instituto Panamericano de Geografia e Historia (IPGH), with financial support from the International Development Research Centre (IDRC) in Ottawa, Canada, asked various regional organizations to put together a comprehensive earthquake catalogue for each of the regions involved in the project. The project area extends form 60°S to 33°N and 30°w to 120°W. This area includes the entire land area of Latin America and the Caribbean and the adjacent oceans. The regions in which the project is divided are México, Central America, South America and the Caribbean.

The region of México was coordinated by researchers from UNAM, with additional support from personnel from other institutions, in particular for the historical section of the seismic catalogue. The general organization of the project followed the main stages of the research activities, namely:

- the historical seismic catalogue,
- the instrumental catalogue,
- the seismic hazard computations,
- the elaboration of maps

Historical Period

For the historical seismic catalogue phase of the project, a team of five history students under the supervision of a historian (Virginia Acosta, from the Centro de Investigaciones y Estudios Superiores en Antropologia Social (CIESAS)) and a seismologist (Gerardo Suárez, from the Instituto de Geofisica of UNAM) recovered as much as possible of the reference material on historical seismicity available from Mexican sources, given the limited duration of the project. Subsequent discussions led to special visits to the *Archivo General de Indias (AGI)* in Seville, Spain. As a result of this effort, an important data base was produced which comprises verbatim accounts of the earthquakes that took place during colonial times as well as their effects on the population and cities and some descriptions from Indian sources of events which occurred during the pre-colonial period. This data base will provide an invaluable source of information for future studies pertaining to seismic hazard evaluations of the country Seismic interpretations were carried out on 18 events which occurred in the historical period.

Even though a few accounts of historical seismic events had been compiled in the past by different researchers, it was seen as necessary to undertake a systematic investigation starting from the most important primary sources known. Thus. a thorough search was carried out collecting data from previously recorded catalogues, diaries, reports in books, traveller's accounts, etc.. Most importantly, all of the main historical archives of the country were visited and searched. The result of this effort was an enormous amount of information recorded in hand-written notes. Subsequently these data were captured in computer form and organized into a sequential file. Originally, the data comprised about 16 mbytes of information residing in a PC-type machine. The information was analyzed to avoid duplication in the reports and only the original (primary) source was kept in the final log.

Parallel to the above-mentioned activities, a visit was conducted to the AGI in Seville where documantation related to the old colonial times of México and Latin America is kept All available information on destructive earthquakes was compiled in its original form, producing first or second hand descriptive files. An experienced seismologist then made size estimates on some of them.

The historical catalogue now spans from the fifteenth to the nineteenth century and includes events documented by Indian codexes.

Instrumental period

For the instrumental period of the catalogue, existing catalogues first had to be examined for inconsistencies. Then, all available information needed to be merged into a single file where references to every data record were also included according to a pre-defined order of precedence. Homogeneity in the methods of magnitude and location determinations was studied in order to find times of change of common practices as well as those when new stations had been put in operation or ceased to function. The completeness of the

catalogues was another important issue, so that an estimate of times and minimum magnitude at which every sub-catalogue is complete could also be provided.

The most important sources for the instrumental catalogue were:

- The epicentre catalogue of the International Seismological Centre (ISC) for the period 1898 to December, 1990. This catalogue was adopted as the reference catalogue - all events within the area of México were included.

- The epcentre catalogue of the United States Geological Survey known as PDE for the period 1898 to December, 1990.

- The Mexican catalogue of instrumental epicenters of the Instituto de Geofisica, UNAM, compiled by R. Zúñiga, listing events for the period 1899-1991

- A number of authors have re-determined epicenters, depths and magnitudes for individual earthquakes within the region as well as estimated their seismic moments. These sources are also included in the catalogue

Sources for the ISC catalogue include several global catalogues as well as their own hypocenter and magnitude determinations based on reports from stations all over the world In the case of duplicated information (various estimates for the same event) a precedence order was defined retaining all available information as secondary sources. This is done so that the precedence order emloyed can be cross-checked in future studies and corrected if need be.

Activities related to the instrumental period of the seismic catalogue were coordinated by R Zúñiga from UNAM with the help of seismology students and other researchers from the Seismology Department of the Instituto de Geofisica. Close to 6400 events, to which a magnitude considered reliable has been assigned, were completed from various sources, following a precedence order agreed upon by the Project Steering Committee. An evaluation of the homogeneity and completeness of the catalogue provided dates during which important changes took place in terms of reporting seismic events. The most important changes were observed for the years 1938, 1967 and 1973, all related to main stages in network capabilities development. Overall, the catalogue can be considered complete for events with $M_S \geq 7.0$ for the years 1900 to 1994 Considereing events with $M_S \geq 6.5$, the catalogue is complete for the time interval 1938-1994. For the years 1964 to 1994, the minimum magnitude for completeness is $M_S = 4\ 3$. It is important to mention that differences exist in the minimum magnitudes as well as intervals of reporting for the various regions of the country. Nevertheless, since it was observed that for those regions where differences are found, magnitudes are even smaller that previously obtained, we conclude that the estimates given are still valid in general Such variations were taken into account for the estimation of seismic hazard.

In terms of hypocentral depths most events have occurred in the upper 50 km of the lithosphere, which is to say that most events are shallow. Also, most events take place in subducting regimes (zones of contact between two tectonic plates where one thrusts under the other), usually inside the subducting plate or at the interface between the two plates.

The catalogue resulting from the analysis was used as a basis for defining seismotectonic regions as well as to provide seismicity estimates for each one. Accordingly, the territory of México was subdivied into 19 regions based on the following criteria:

- the hypocentral location of events,
- tectonic characteristics of the zone where events are located,
- focal mechanisms and/or fault patterns - this was accomplished based on several sources including data on aftershock focal mechanisms, microseismicity (to detemine alignments) and swarm activity.
- seismic history - historic events were also considered when delineating the boundaries of the regions - this was emphasized in those cases where current activity is too scarce and for those which do not report large events during the instrumentally recorded period, but can still be considered potentially dangerous.
- finally, an additional criterion was to reduce the number of regions to a minimum with the goal of assigning common characteristics of interest for seismic risk evaluation to the region thus defined - this was also done so that a first order regionalization of the country could be produced without introducing any bias due to variations in the distribution of seismic stations - as more data of improved quality is gathered, it will be possible to subdivide each region.

Seismic hazard computation

It is usually not possible to determine how frequently a certain seismic intensity is exceeded based solely on local data. This is due to the scarcity of data and, on occasion, even to a complete lack of it. It is thus necessary to estimate it through studies of seismic sources and of attenuation of seismic waves with distance. Such studies provide relations between type of source and intensity of ground motion at a particular site of interest.

Researchers headed by a specialist on seismic risk analysis, M. Ordaz of the Instituto Ingenieria, UNAM, and the Centro Nacional de Prevención de Desastres (CENAPRED) were in charge of the seismic hazard computations and the generation of the final maps for México. Seismic events of interest for the analysis were divided into three main categories; subduction, intermediate depth and shallow continental type events. In the dase of subduction events it was assumed that the seismic generation process could

be divided into two further categories: for those events for which $M < 7.0$, it was assumed that the process could be described as having a Poisson distribution in time, whilst for events for which $M \geq 7$, the process was assumed to follow a "characteristic event" which implies repeatability in time. All other events were assumed to follow a Poisson distribution. Rates of exceedance and other parameters of interest like maximum magnitude (M_U) were estimated for each of the proposed regions using Bayesian statistics based on the data available in the catalogue.

Attenuation relations were calculated for shallow subduction events and for intermediate depth events. A maximum acceleration relation for short hypocentral distances was determined for subduction events using a theoretical finite-length source model, since, in the case of mexican earthquakes, it has been observed that peak acceleration reaches a saturation value in the near source field. For long distances, the attenuation law was determined by means of a regression on observed data. The case of intermediate depth events was treated by means of a theoretical spectral source model known as ω^2 with fixed parameter values. Seismic hazard values were computed for all of México, obtaining a map of peak ground acceleration for a 500 yr return period.