

Current knowledge on the Central America historical seismicity: an analysis of recent catalogues

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Abstract

Historical seismicity studies in Central America have increased since 1980. Currently, there is a well-organized regional digital catalogue database structured according to modern techniques. It contains more than 17 000 earthquakes which occurred between 1520 and 1992. A regional tsunami catalogue is also available. The historical seismicity research included a more complete earthquake documentation obtained from foreign and Central American depositories. New intensity data point estimates and isoseismal maps allows among others, macroseismic magnitude calculations and seismogenic source determinations, for many pre-1900 earthquakes. Future trends in Central America historical seismicity research are discussed.

Key words *Central America – historical earthquakes – catalogues*

1. Introduction

Central America has an important seismic and volcanic activity due to the interaction of several plates (fig. 1). That activity has conditioned its economic and social development. In order to define the seismic hazard of this region, a necessary step is to collect seismicity data by means of «earthquake catalogues». In order to have a better understanding of the different earthquake sources and its activity rates, historical earthquake information must also be included. For this reason, during the last two decades important research efforts have been conducted in historical seismicity

(pre-instrumental earthquakes) and on developing a digital catalogue for this region.

Before 1980 there were some valuable regional and national catalogues, although the information they contain was scattered in different reference sources. Also, modern techniques were not applied to integrate the regional pre-1900 earthquake information in a systematic and methodical way. However, since 1980 there has been a remarkable increase in the historical seismicity investigation at regional and local levels, and its results have been partially incorporated in a digital catalogue. In the next paragraphs we review the previous work with especial emphasis in the historical seismicity research topic (pre-1900 earthquake studies).

2. Pre-1980 descriptive earthquake catalogues

Research and compilations of the Central American destructive earthquakes which occurred since the Spanish Conquest in the 16th century up to 1900 are found in different works.

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At the Central American level, the principal compilations came from Montessus de Ballore (1888), Sapper (1925), Díaz (1933) and Grases (1974). At national level we mention González (1910) for Costa Rica; Lardé (1960) and Martínez and Maximiliano (1978) for El Salvador and Kirkpatrick (1920) for Panamá. All the previous works were descriptive catalogues compiling historical earthquake information, but they do not include intensities or isoseismal estimates or define focal parameters obtained from macroseismic information.

3. Current earthquake and tsunami catalogues

Currently, descriptive and parametric catalogues, and a mixture of both are found in Central America. Leeds (1974) compiled for Nicaragua, the first published parametric catalogue including pre-1900 earthquake information for a Central American country. After this publication, other parametric catalogues were compiled. Sutch (1981) published one for Honduras; White (1984) produced one for the Polochic-Motagua fault system of Guatemala; Miyamura (1980) and Montero (1989) published catalogues for Costa Rica and Viquez and Toral (1987) published one for Panamá. The previous catalogues also included instrumental seismicity.

Rojas (1993) and Rojas *et al.* (1993) carried out the main seismological digital parametric catalogue currently existing at the regional level. They included information of around 17 000 earthquakes which occurred between 1505 and 1992. This catalogue gathered seismological information from the previous catalogues and other diverse reference sources, although no archival or any specific earthquake investigation was conducted. The catalogue merged the instrumental and macroseismic information applying the Standard Nordic Format, which includes three files: 1) *The Main Catalogue file* includes the main focal parameters of the event, as well as the possibility to include several entrances for any event. It includes instrumental and macroseismic event information. 2) *The Catalogue file* is a bridge that connects files 1 and 3. 3) *Extensional files* include additional information of the

event, such as macroseismic data and references, among others. For some earthquakes intensity data points are included.

Besides the parametric catalogues, national and regional descriptive or mixed catalogues were compiled. Feldman (1985, 1986 and 1993) gathered from diverse archives a large number of new primary documents about destructive earthquakes which occurred in Guatemala and in Central America between 1500 and 1899. He compiled descriptive catalogues, not including intensity data or isoseismal maps.

Peraldo and Montero (1999) published a mixed earthquake catalogue including information obtained from archives and other different reference sources. They studied Central America destructive earthquakes which occurred from 1469 to 1899 and obtained new seismological interpretations such as intensity data points, isoseismal maps and macroseismic focal parameters. Figure 1 shows the epicentre locations and the suggested seismogenic sources of the historical earthquakes studied by Peraldo and Montero (1999).

In relation to 20th century Central America seismicity studies, we briefly review two important recent works, among other valuable specific or national studies. We mentioned the work of Ambraseys and Adams (2001) who gathered instrumental and macroseismic information on Central American earthquakes which occurred during the period 1898-2000. The study includes a regional descriptive and parametric catalogue, and maps with macroseismic locations but without intensities estimations. They also obtained new magnitude calculations for a considerable number of events. On the other hand, White and Harlow (1993) studied the upper crust Central American earthquakes which occurred since 1900. They obtained magnitudes for several of the shocks and compiled isoseismal maps for some damaging earthquakes. An important number of earthquake specific studies are also found in the literature but they will not be reviewed in this article. For a general overview see for instance Peraldo and Montero (1999) for pre-instrumental seismicity and Ambraseys and Adams for 20th century seismicity.

The occurrence of tsunamis is another kind of earthquake hazard related phenomenon in

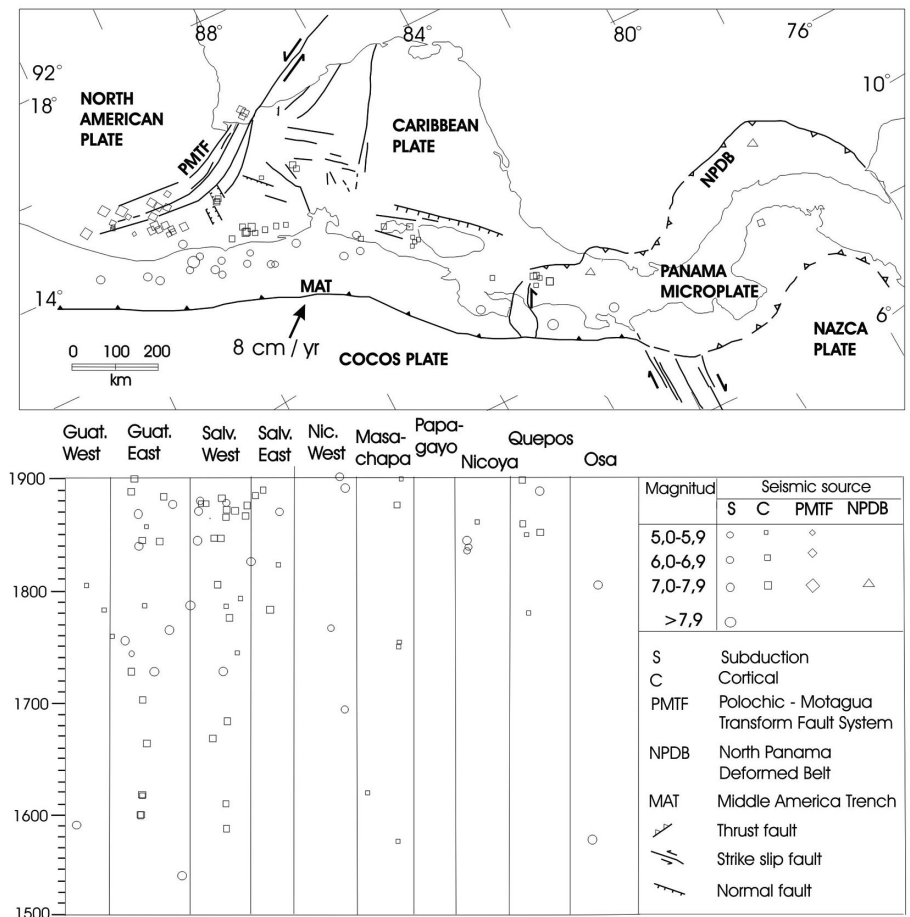


Fig. 1. Spatial-temporal historical seismicity along the different Cocos-Caribbean plate boundary convergent segments (blank circle events). Also shown are the epicentre locations related to other regional seismogenic sources. The large number of earthquakes shown for Northern Central America is explained by its early colonization and its relatively larger development during the Colonial period. The scarce seismic activity of the Caribbean side of Central America is also shown (modified after Peraldo and Montero, 1999).

Central America. A recent tsunami catalogue was compiled for this region (Molina, 1997; Fernández *et al.*, 2000).

4. Scope, professional background and financial research agencies since 1980

As a result of the research carried out in historical seismicity of Central America since 1980,

now there are improved and more complete catalogues. They constitute the fundamental tool to obtain better seismic hazard estimates. Seismologists and historians, working in separate or in interdisciplinary ways carried out the investigation. However, according to our experience, a previous work of interdisciplinary investigation, including the analysis of the historical context where the seismic event took place, favors better seismological interpretations.

Table I. Main characteristics of Central America seismological catalogues.

Authors	Year	Type	Period	Catalogue type	Format	IDP or intensity map	Intensity Scale	Financial Agency
Rojas	1993	Parametric	1505-1992	Compiled seismological information	D	Partially	MM	NORAD, UCR
Feldman	1993	Descriptive	1500-1899	Primary Historical information	P	No		AID, USGS
Peraldo and Montero	1999	Descriptive and parametric	1469-1898	Mixed	P	Both	MM	PIGH, IDRC, UCR
Ambraseys and Adams	2001	Descriptive and parametric	1898-1995	Summary of seismological information	P	No		CEC, ISC

D = digital, P = printed; IDP = Intensity Data Point; MM = Modified Mercalli.

Most of the investigation performed by historians has been focused toward finding new primary information in diverse archival sources. We here highlight the work carried out by the historian Feldman (1993) at the regional level, investigation that received financial support of the Agency for International Development (AID) and of the United States Geological Survey (USGS). Also, the historians Hilje and Alvarez (1994) carried out a similar research in Costa Rica, work financed by the Pan-American Institute of Geography and History (PIGH).

In 1992, the geologist Peraldo and the historian Claudia Quirós gathered primary historical Central American seismological information from different archives. It was used together with other documents and references in the seismological interpretations carried out by Peraldo and Montero (1999). The historical context of the seismic events was considered in their interpretations. The previous investigators received financial support from the PIGH through a project financed by the International Development Research Centre of Canada

(IDRC). Also, they obtained local support from the University of Costa Rica (UCR). The seismological analysis carried out by these authors is somehow extensive and focused on studying most of the pre-instrumental destructive regional events.

The digital regional parametric catalogue merged by the seismologists Rojas (1993) and Rojas *et. al.* (1993) was supported by the Norwegian Agency for International Cooperation (NORAD). The 20th century seismicity study carried out by the seismologists Ambraseys and Adams (2001) was financed by the National Scientific Cooperation Programme of Brussels (CEC) and the International Seismological Centre of England (ISC).

Table I summarizes the characteristics of the recent regional catalogues.

At the national level, Peraldo and Montero (1994) using primary and secondary sources studied the Colonial seismicity of Costa Rica. This work, that includes seismological interpretations, is considered quite intensive, because the archival sources were intensely reviewed, although only few Costa Rican colonial time

earthquakes were documented. The University of Costa Rica supported this work. In Panamá, Camacho and Viquez (1993) studied the historical seismicity of the North Panamá Deformed Belt, a seismic source area located on the Caribbean side of Panamá and Costa Rica (fig. 1). The Pan-American Institute of Geography and History and the University of Panamá supported this research.

5. Primary information sources

The documents found in archives and libraries including seismic phenomena descriptions from the Spanish time up to 1821 (1903 for Panamá as an independent republic), are chronicles, reports and correspondence elaborated by conquerors, governors, ecclesiastical authorities, among others. After 1821, Municipal and Government archive documents, ecclesiastical reports, newspapers reports, and naturalist and travellers' chronicles, especially by foreign people, also record damaging earthquakes that affected the Central American republics. That historical data baggage constitutes the basic primary information with which the diverse seismological Central American catalogues have been elaborated since the end of the 19th century. The primary source reports have been obtained from archives and libraries of Europe and America. They include, among others, the *Archivo General de Indias* and of Simancas, *Museo Naval* of Madrid and *Biblioteca Nacional* (Spain), *Archivo General de la Nación* (México), *Archivo General de Centro América* (Guatemala), *Archivo Nacional* and *Archivo Eclesiástico* of León (Nicaragua), *Archivo Nacional* and *Archivo Eclesiástico* of the Curia Metropolitana of San José (Costa Rica).

Let us briefly review the depositories researched at the regional level. Feldman (1993) carried out a profuse investigation in different archives and libraries, including several of those mentioned previously. Peraldo and Montero (1999) carried out their investigation based on documents obtained from archives of Spain and Central America, and compiled other primary and secondary documentary sources. Am-

braseys and Adams (2001) gathered historical and seismological information published by diverse authors.

At the national level, the depositories researched by Hilje and Alvarez (1994) and by Peraldo and Montero (1994) were the Costa Rican archives. Camacho and Viquez (1993) researched the Canal of Panamá Library, the *Archivo Nacional* and the *Biblioteca Nacional* of the Republic of Panamá, the *Biblioteca Simón Bolívar* of the University of Panamá and the *Archivo Nacional* and the *Biblioteca Nacional* of the Republic of Colombia.

6. Intensity scales used

The scale used to estimate the levels of intensity in the diverse studies carried out on historical seismicity in Central America has been the Modified Mercalli intensity scale (MM). Exceptionally, the intensity scale MSK (Medvedev-Sponheuer-Kárník) or its later modifications was applied. Rojas (1993) gathered some historical earthquake MM intensity data in digital format. Peraldo and Montero (1999) assigned MM intensity levels to Central American earthquakes and drew isoseismal maps when enough estimates of intensity existed. Otherwise, they only showed maps with intensity data points, as is the case of most of the earthquakes of the Costa Rican colonial period studied in Peraldo and Montero (1994). The MM intensity scale was also used by Camacho and Viquez (1993) and by White and Harlow (1993), among others.

7. Catalogue completeness

According to Rojas *et al.* (1993), the Central American catalogue is reasonably complete for earthquakes of $M_s \geq 5.5$ from 1900 and of $M_s \geq 7.0$ from around 1820. Ambraseys and Adams (2001) consider their catalogue complete for earthquakes of magnitudes $M_s > 5.0$ starting from 1920 and of $M_s > 6.0$ starting from 1910. Table II shows the earthquake number per century included in different catalogues. Figure 2 shows the historical accumulative

earthquake number found in Peraldo and Montero (1999). A remarkable slope increment in the seismicity reported is shown around the beginning of the 18th century, probably related to the consolidation of the Spanish colonial period and accordingly, to a better documentation of the historical earthquakes.

8. Difficulties and solutions in historical research

Several difficulties were found during the historical seismicity research and among these we emphasize: i) Manuscript reading difficulties related to the grammatical and calligraphic language evolution, especially from the old to the modern Spanish. This problem has been partially solved with the participation of historians trained in paleography or in the case of professionals coming from other fields, by learning paleographic techniques; ii) Physical deterioration of the documents caused by improper conservation, humidity damage, ink scattering, writing fading and paper destruction caused by fungi and diverse animals; iii) Document losses due to such diverse causes as fires and robberies; iv) Document misadministration including inadequate classification and

improper organization of the historical material and inappropriate loan practices; v) Scattered archival information, in some cases occurring in different document series in the same archive or between distinct depositories, many of them difficult to access; vi) Changes in the nomenclature of towns and localities or wrong geographical locations; vii) Physical disappearance or seat change of populations; viii) Earthquake dating errors included in primary and secondary reference sources. An example of an error in the event occurrence date is found in González (1910), who based on a municipal record, mentioned an earthquake which occurred on 3 April 1827, in NW Costa Rica. However, a primary source located by Peraldo (1993) in the Government File of the Costa Rican National Archive referred the occurrence of an earthquake on 3 April 1826, in the same region. This leads Peraldo (1993) to propose that the earthquake occurred in 1826 instead of 1827, something sustained by the new investigations carried out by Montero and Peraldo (work in progress). For instance, a municipal record dated 4 April 1826, from Alajuela town, located east of the epicentral region, explicitly mentions the occurrence the day before of a strong earthquake that caused some damage.

Table II. Number of earthquakes included in the seismic catalogues.

Authors	Type	Period	16th c.	17th c.	18th c.	19th c.	20th c.	Total
Rojas (1993)	Parametric	1505-1992		98	92	300	16 698	17 188
Feldman (1993)	Descriptive	1500-1899	37	45	66	217		365
Peraldo and Montero (1999)	Descriptive and parametric	1500-1899	16	22	65	70		173*
Ambraseys and Adams (2001)	Descriptive and parametric	1898-1995	–	–	–	6	1823	1829

(*) This study investigated the earthquakes with intensities MM larger than VI.

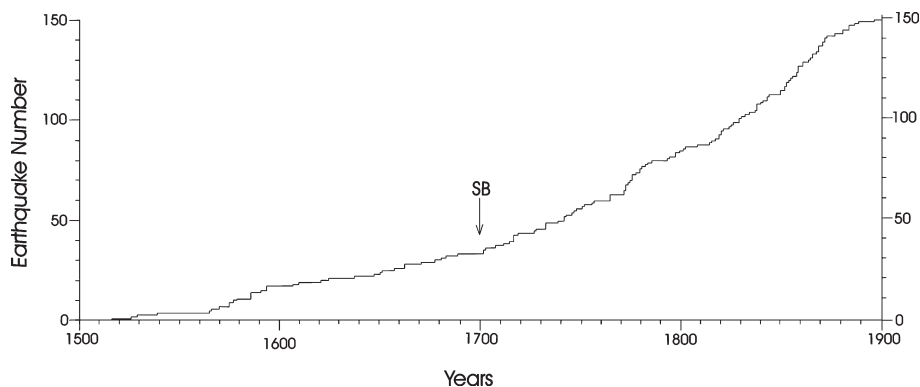


Fig. 2. Temporal variation of the accumulative number of events according to Peraldo and Montero (1999). The graph incorporates only well documented seismic events. The absence of appropriately documented damaging earthquakes is evident for the period between 1500 and 1700. Some periods of apparent seismic quiescence are identified at regional level between 1540 and 1565, 1594 and 1607 and 1625 and 1648. Starting from the 17th century the slope increases, indicating a better documentation due to the consolidation of the Spanish colonization process. Also, the periods of apparent seismic quiescence shorten.

An important aspect that must be analyzed carefully in any historical earthquake research is the historical conditions prevailing at the time the documents were written, including the specific political and social situation. Examples are the August and September 1717 and the July 1773 seismic sequences, that affected the city of Antigua, Guatemala (Peraldo and Montero, 1996). In both cases, a series of documents suggest widespread city destruction allowing some authorities to propose its relocation. On the other hand, another group of documents refers major damage although with remarkable exceptions and in this case other authorities argue that the city should remain in the same location. In this case two opposed political factions existed, with different concerns about the necessity or not of the city relocation, partially because they had different property damage level assessments. Both theses also reflected a power fight between Clergyman and the «*Real*» authorities. The identification and opposition of the different document discourses and their historical explanation allowed a better estimate of the damage level produced by those earthquakes.

9. Current knowledge status and future work

The seismic history before the Spanish arrival in Central America shows an information gap because only few documentary sources have been identified. The principal ones are the Popol Vuh, the Memorial de los Cackquiqueles, and the interpretation of indigenous narratives, although they do not necessarily correspond to the pre-Hispanic period (Peraldo and Montero, 1994; 1999). A possible solution to expand the historical seismicity record to the pre-Spanish epoch would be to increase paleoseismological investigations with the objective to identify and date paleoearthquakes. Another way would be to begin research in seismic archaeology, because it is possible that some earthquakes affected the physical and social structure of some Central American indigenous cultures, especially those from the Mayan period.

In relation to the seismicity which occurred between 1500 and 1900, a first investigation phase in future research would be to evaluate the information contained in the catalogue of

Rojas (1993). A necessary step will be to update that catalogue with the new historical seismological information that has been generated since 1993 at regional and national levels. By doing so, the seismic parameters information incorporated in Peraldo and Montero (1994, 1999), Ambraseys and Adams (2001) and other newly published works including some intensive studies of earthquakes, can be incorporated in that catalogue.

A second phase would consist in carrying out a systematic and careful evaluation of the historical records gathered in the diverse archives, libraries and reference sources explored. A good approach to proceed can be found in Guidoboni and Stucchi (1993), where very useful guidelines are found to review the historical documentation. With regard to the primary documentation of earthquakes from the conquest up to the end of the 20th century, it is considered that the investigation carried out until now by the diverse authors has been in general extensive and not intensive. The next objective will be the identification of the most important destructive events that still have not been studied intensively, in order to proceed to its investigation in promissory local, national and foreign little explored archives.

One important step of any future historical intensive investigation should be to increase the completeness of the Central America seismic catalogue, including the search for new events and a better documentation of those not well known. Finally, the procedures followed in estimating earthquake parameters from macroseismic data must be reviewed and some homogeneous and robust criteria must be identified to obtain well-supported macroseismic earthquake parameters.

Finally, seismicity studies for the 20th century would benefit from macroseismic studies, such as defining intensities and isoseismals for specific damaging earthquakes, because this important research tool can better constrain the earthquake focal parameters. This is especially true for events which occurred during the first six decades of that century, because some damaging shocks before 1960 had a magnitude level below the world seismographic network de-

tection capacity. For that reason, their instrumental magnitudes were poorly or not determined. Another problem is that the instrumental epicentres were poorly constrained due to the scarce coverage of the world seismographic network before 1960.

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