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The Philippine historical earthquake catalog: its development, current state and future directions

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Abstract
This report will trace the development of the historical earthquake catalog of the Philippines, assess its present state and recommend future research directions. The current Philippine historical earthquake catalog is culled from various catalogs, both global and local, that were developed since the first Philippine catalog by Perrey was published in 1860. While early global catalogs gave simple mention of earthquakes in the Philippines, more focused earthquake catalogs about the Philippines gave more explicit descriptions of earthquake accounts and adopted descriptions by local historians. Over the years, various historians and seismologists continued to compile their catalogs whose contents depended on the author's perspectives and purposes. These works varied from simple listings to others including detailed descriptions. It was only recently that an attempt made to parameterize the magnitudes and epicenters of Philippine historical earthquakes using magnitude-felt area relations was done. A more detailed catalog, however, is now underway that will show details of intensity distribution for each significant historical earthquake. By comparing the historical catalog with the recent catalog and assuming that the recent catalog is complete, we find that there are still a substantial amount of historical earthquakes that needs to be reviewed and located. Possible sources of new information are local libraries, museums and archives in the Philippines, Spain and other Southeast Asian countries to which the country was in contact with during historical times.

Key words *historical earthquake catalog – Philippine earthquakes – seismic hazard assessment – archival documents – historical accounts*

1. Introduction

Reliable seismic hazard studies depend on having a robust earthquake catalog. The longer the extent of the catalog and the more reliable the parameters are, the better it is for those doing seismic hazard analysis. There are two kinds of earthquake catalog: one is the instrumental or recent catalog and the other is the historical catalog. In this study, instrumental or recent catalog refers to the time when seismic monitoring existed while historical refers to the pre-instrumental period. In the Philippines, instrumentally-derived parameters are available for events from 1892 onwards. The year 1892 was selected because the first earthquake with instrumentally derived parameters was determined by Abe (1994) for an earthquake in 1892. The historical period for the case of the Philippines could be considered as covering the period before 1892. Unlike other countries with long earthquake histories and despite the

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Philippines being seismically active, the Philippine historical catalog is not that long compared to other countries. The historical accounts only started during the time when the country was conquered by Spain in the late 15th century. This study will discuss the development of the historical earthquake catalog in the Philippines, assess its present state and recommend future directions.

2. Existing catalogs

The current Philippine historical earthquake catalog is culled from various catalogs, both global and local, that were developed since the first Philippine catalog by Perrey was published in 1860. Early global catalogs made simple mention of earthquakes in the Philippines. Meanwhile, catalogs that mainly focused on the Philippines gave more explicit descriptions of earthquake accounts and adopted descriptions by local historians.

Over the years, various historians and seismologists kept on building their own catalogs whose contents varied depending on each author's perspective and purpose. For example, some authors would make simple listings of earthquakes while some would include detailed descriptions. Some authors would only list tsunamigenic events. Others gave their own intensity estimates as well as drew their own isoseismal maps. A recent work by Bautista and Oike (2000) has parameterized the magnitudes and epicenters of well-described Philippine historical earthquakes using magnitude-felt area relations.

2.1. *Global earthquake catalogs*

It was only when colonization of the Philippines started in the late 15th Century that earthquakes affecting the country started to be noticed and documented. These earthquake citations may be grouped into those cited in global catalogs while the other group belongs to the country-specific catalogs. Global earthquake catalogs such as those made by von Hoff (1841), Mallet (1853, 1854, 1855) and Milne (1912) mentioned earthquakes about the Philippines. The work of von Hoff (1841), written in German, listed three earthquakes and three volcanic eruptions in the Philippines. Mallet's works were in English and among his references were the works of De Guignes (1808), Garnier (1839) and articles from the Singapore Chronicle (1824, 1829). Meanwhile, Milne (1912) listed 66 Philippine historical earthquakes from 1589 to 1909 in his catalog. His source is mainly the work of Maso (1895). More recently, Dunbar *et al.* (1992) listed epicenters, magnitudes and damages attributable to Philippine earthquakes from 1599 to 1990. Meanwhile, some authors listed tsunamigenic earthquakes only (Rudolf, 1887; Heck, 1947; Iida *et al.*, 1967; Berninghausen, 1969; Cox, 1970; Nakamura, 1978). Reviewing global data since 1616, Iida *et al.* (1967) listed 26 tsunamigenic earthquakes in the Philippines. They also listed the areas affected and estimated heights based on descriptions. Berninghausen (1969), meanwhile, listed tsunamis in Southeast Asian region which included 29 events in the Philippines. His database covered the period 416 to 1965. The various works of Abe (1981, 1984, 1994) and Abe and Noguchi (1983) especially their redetermination of the magnitudes by Gutenberg and Richter covering the early 20th century period helped to improve the earthquake data in the Philippines including those during the 1892 to 1900 period.

2.2. *Country-focused historical earthquake catalogs: Philippines*

While the earliest earthquake reported for the Philippines was the one which happened in 1589, the first known country-focused earthquake catalog for the Philippines is the work of Perrey (1860) which was in French. This catalog described both earthquakes and volcanic eruptions in the Philippines from the 15th to 18th centuries starting with an earthquake in 1601. His sources included various European travellers in Asia who wrote books, chronicles or accounts of their travels. Despite exaggerations and misquoted names of places, Perrey's work became one of the most referred to earthquake catalog for the Philippines.

The creation of the Manila Observatory in 1865 paved the way for the systematic collection of earthquake reports in the country. Maso, a researcher at the Manila Observatory, published an earthquake catalog in 1895 written in Spanish. His work could be considered the first attempt to document the historical accounts made by Spanish priests about earthquakes affecting their localities. His work is more comprehensive than that of Perrey, although the main difference is that it dealt exclusively with earthquakes and excluded volcanic activities. His work also included the observations of the Manila Observatory and its various stations in the provinces. In addition, Maso also drew isoseismal maps of selected large earthquakes using the Manila Observatory Intensity Scale of I to VI (table I). Later, culling much from the work of Maso, Algue (1900), who was also from the Manila Observatory, published his own catalog covering the period 1870 to 1897.

In 1901, after the Spanish conquerors had left the country, the new American government reorganized the Manila Observatory and created a Philippine Weather Bureau. Aside from weather monitoring and forecasting, the Bureau also conducted seismic monitoring. Maso continued on his compilation and updating of earthquake events and published several catalogs (Maso, 1909; 1927, Maso and Smith, 1919). The 1895 and 1927 Maso catalogs have basically the same contents except that the 1927 version only contained the damaging events. In 1928, Fr. William Repetti joined the Manila Observatory and the Philippine Weather Bureau. He was placed in charge of all seismological stations in the Philippines. He was Chief of the Section of Seismology and Terrestrial Magnetism of the Philippine Weather Bureau for more than a decade. In 1946, Repetti published the most comprehensive historical catalog of the Philippines covering the period 1589 to 1899. Repetti translated various accounts written in various languages into English. Repetti's work included the results of Perrey and Maso and at the same time included other accounts culled from history books, bulletins, letters and newspaper articles.

Table I. Manila Observatory Intensity Scale (after SEASEE, 1985).

Intensity	Description
I	Perceptible
II	Light
III	Regular
IV	Strong
V	Violent
VI	Destructive

After World War II, the Weather Bureau was reorganized into the Philippine Atmospheric, Geophysical, Astronomical and Services Administration (PAGASA). In 1982, the Office of Foreign Disaster Assistance (OFDA) of the United States Agency for International Development (USAID) undertook a project called «Seismic Data Gathering, Southeast Asia». This project was undertaken under the auspices of the Southeast Asia Association on Seismology and Earthquake Engineering or SEASEE. Among the projects of SEASEE is an earthquake catalog published in 1985 that compiled Repetti's historical data, instrumental data from the Manila Observatory and PAGASA (1976) as well as reports of investigations of earthquakes from 1950 to 1983 (SEASEE, 1985). Aside from these, the SEASEE catalog also included earthquake data determined for the Philippines by Gutenberg and Richter (1954), Gutenberg (1956), by the International Seismological Centre (ISC) and the U.S. Geological Survey (USGS).

The SEASEE catalog was divided into eight chapters: i) Catalogue of Philippine Earthquakes 1589-1864; ii) Catalogue of Philippine Earthquakes 1865-1899; iii) Catalogue of Philippine Earthquakes 1901-1942; iv) Catalogue of Philippine Earthquakes 1948-1983; v) Catalogue of Destructive Earthquakes 1589-1983; vi) Assessment of Seismic Intensity of Philippine Historical Earthquakes; vii) Seismic Source Zones of the Philippines, and viii) Seismotectonics of the Philippines. The result is an 843-page compilation of earthquakes from 1589 to 1983.

Although some of these previous works, including the SEASEE catalog, estimated epicen-

ters, maximum intensities and even contained isoseismal maps, there was no attempt to make a systematic parameterization of these historical earthquakes to determine their magnitudes and epicenters. The first attempt was made by Bautista (1993) who made use of magnitude-intensity at epicenter (I_o) relationships derived from Philippine earthquake data to infer the sizes of Philippine historical earthquakes. Later on, Bautista (1996) revised her empirical equations through the addition of more recent events and developed new empirical equations relating magnitude to felt area for various intensity levels.

The same study estimated the epicenters and magnitudes of 74 historical earthquakes. A more extensive work by Bautista and Oike (2000) reviewed the historical accounts of more than 3000 earthquake events from 1589 to 1895. From these events, they were able to estimate the magnitudes and epicenters of 485 historical earthquakes in the Philippines. While there were 3000 earthquake events, most of these were either felt only in one area or had no damage reported. Only these 485 events were sufficiently described or could be assessed for parameter determination. Meanwhile, as guides to future users of the catalog, their study also gave a quality assessment for each earthquake. This quality assessment is based on the number of places where accounts are available. To have a higher quality, an earthquake should have many accounts for many different places. Having numerous accounts but limited to one place would still mean a lower quality of reporting. Out of the 485 events, quality «A» was given to earthquakes with 10 or more reporting places, «B» to those with five to nine reporting places and «C» to those with four or less number of reporting places. Using these criteria, they found out that only 52 of the total 485 events may be considered very reliable (quality A) and 80 events as quite reliable (quality B). The remaining events were given quality C and their determined parameters are not considered so reliable.

3. Issues and concerns

Inaccuracies, exaggerations and biases sometimes creep into interpretation of historical accounts. Thus, it is always better to go back to the primary source of information.

The search for new sources of information started from the original list of references by previous authors. The original list has since more than doubled and potential new sources of information are now being considered. The only issue is how to find or locate these references for historical earthquake evaluation.

Meanwhile, aside from other factors such as change of names and jurisdiction, it is also important to consider knowledge of local history, geography and existing socio-political conditions when these earthquakes occur when reviewing historical earthquakes. Samples of such errors were cited in Bautista and Oike (2000). One example is after an earthquake in 1645, when only the Spaniards who perished during the earthquake were counted, while persons of «no account» were disregarded. Since the number of casualties are, at times, used to gauge how damaging an earthquake was, the results from this procedure of counting could give quite misleading results.

Meanwhile, knowledge of local geography is also important. Errors in naming places can be discerned if one is familiar with local geography. For example, the name of a place called «Cagayan» was changed by Perrey (1860) into «Camarines» for an earthquake in 1627, when in fact the two places are 400 km apart.

To solve such kinds of issues for various cases, it was always important to find out which place was actually affected by getting the information from the original source, if available, or by relating existing accounts with one another.

4. Status of the Philippine historical catalog

After Bautista and Oike (2000) have determined the epicenters of 485 historical events, they also evaluated the completeness of the resulting historical catalog.

They plotted the typical yearly number of earthquakes with M 6.5 and above for the Philippines for both the historical and recent periods. They found out by comparing the historical catalog with the recent catalog and assuming that the

recent catalog is complete, that there are still a substantial number of earthquakes that need to be reviewed and located especially during the period from 1600 to 1850. On the other hand, they also found out that earthquakes that occurred from the period 1850 to 1900 are almost completely reported. Instead, what is missing in the catalog for the same time period are events with magnitudes lower than *M* 6.5 (fig. 1).

5. Future directions

The continued search for new information to cover the 1600 to 1850 period for all magnitude ranges and from 1850 to 1900 for magnitudes less than 6.5 will be actively pursued. Among the possible sources are local libraries, museum and archives, libraries in Spain and in Southeast Asia.

Spanish-era old churches in various towns are also promising sources as some of them keep records of when they were damaged by natural phenomena while some of them maintain a museum or archive. Specific books on town histories are another potential source of earthquake histories.

The Internet offers information, although it should still be verified, about histories of churches, dates of their constructions, effects of calamities, architectural styles and many other details. The Mindanao area in southern Philippines where the Muslim mosques are found is also a fresh avenue of research considering that previous research concentrated mainly on accounts from a Christian perspective.

The geoscientific institutions, archives and libraries around the Philippines are also another source of possible new information that must be searched on further.

The National Records and Archives Office of the Philippine National Library is another promising source of data. As it is, archival

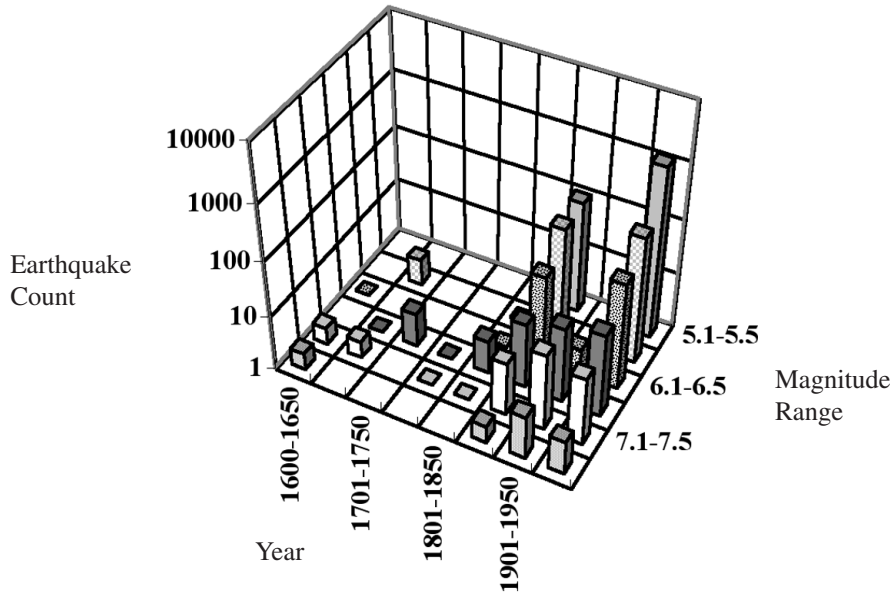

Fig. 1. Number of earthquakes per 50-year period in the Philippine earthquake catalog. By assuming that the recent period from 1900-1997 is complete, the historical period 1850-1900 may be considered well reported and almost complete, too. Meanwhile, there are still many earthquakes that need to be discovered during the earlier period from 1600 to 1850 (table after Bautista and Oike, 2000).

documents on some historical earthquakes and volcanic eruptions which were not seen by previous authors including Maso and Repetti had already been found. They are all handwritten and in Spanish. They were written by governors, military commandants, priests, mayors and other government officials and may be considered as the official damage reports for these earthquakes. However, they are difficult to read and translate because they were handwritten in very complicated hand characteristic of old Spanish documents. But their scientific value cannot be overemphasized because they are able to add significant information to these earthquakes. An initial project to have these translated properly is a possible future action.

Another future activity envisioned is the eventual production of a catalog that will show the detailed intensity distribution of most of these well-described historical earthquake events. Aside from the inclusion of the isoseismal maps, this Philippine catalog will include the tabulation of the individual earthquake accounts for the period 1589 to 1899. These tabulated accounts will be further categorized for easy usage into structural damage, effects to people, effects to the environment, human and economic loss estimates, references, and their assigned intensities.

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