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A provisional catalogue of historical earthquakes in Indonesia

Earth Hazards and Systems Programme

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BRITISH GEOLOGICAL SURVEY

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Foreword

This report has been prepared in the context of the Global Earthquake History project, a module of the Global Earthquake Model (GEM) project. It presents a preliminary analysis of historical earthquakes in Indonesia, in order to supply (at least provisional) parameters for historical earthquakes in Indonesia for the Global Large Historical Earthquake (GLHE) catalogue.

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Summary

This report presents a parametric catalogue of earthquakes in Indonesia considered to be greater than 7 Mw in magnitude, up to the end of 1903. Owing to a lack of intensity datapoints (IDPs) for these earthquakes, parameters are necessarily derived in a somewhat approximate way. The catalogue is to some extent based on previously existing databases such as that of NOAA, but entries have been checked against original data where possible. Thirteen major earthquakes not in previous databases have been identified and included.

This catalogue does not represent a systematic examination of available historical material, of which there is much. This represents a task for a future project, which is likely to take some years to complete. It is very likely, also, that much original material still awaits recovery from European archives.

The catalogue appears to be more or less complete for 7 Mw for the Sunda Arc (Sumatra to Timor). It is incomplete for the rest of the area. This is partly due to the difficulty of identifying large deep earthquakes from the historical record. For shallow earthquakes in the Moluccas, the catalogue is reasonable after 1850 but probably not complete. For New Guinea and New Britain, the catalogue is seriously incomplete for all periods.

1 Introduction

In the scope of the Global Earthquake History (GEH) project, Indonesia presents one of the most challenging areas. It is a highly seismic region, but there is an acute lack of previous studies or parametric catalogues, and particularly, there appear to be no indigenous seismologists working on this subject. A further difficulty is presented by the history of the region itself; records are likely to be scattered amongst archives in the Netherlands, Portugal, France and the UK, rather than being concentrated in local archives. This makes it a difficult subject for local institutes to devote themselves to.

The major ongoing initiative is a study of historical earthquakes in Indonesia that has continued for some years at Brigham Young University, Provo, Utah, under the leadership of Ron Harris (Harris and Major 2012). Since this study is not expected to produce a parametric catalogue within the timeframe of GEH, this present report is intended to provide a stop-gap, so that reasonable parametric values can be included in a catalogue of global historical earthquakes for GEM.

For the purposes of this report, "Indonesia" is considered a geographical term devoid of political import, and is defined as the area between 7° N and 11° S, 93° E and 154° E, excluding earthquakes between 120° E and 130° E north of 5° N, which are associated with the Philippines.

The time window for the report is from the earliest records to 31 December 1903, and the lower magnitude limit is 7.0 Mw (estimated).

2 Data sources

Four inputs were selected for this study, as follows:

1) The Significant Worldwide Earthquakes database of the USGS National Earthquake Information Center (NEIC) (http://earthquake.usgs.gov/earthquakes/eqarchives/epic/)
2) The Significant Earthquake Database of the NOAA National Geophysical Data Center (http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=1&d=1)
3) Utsu (2002) updated at http://iisee.kenken.go.jp/utsu/index_eng.html
4) Newcomb and McCann (1987)
5) Wichmann (1918, 1922)

The first two of these are nominally the same; the USGS page links to the NOAA page as its source, and both appear to derive from Dunbar et al. (2002). However, in fact they are quite different, and it is not a matter of the USGS database being a selection of events from the NOAA database, since the USGS database contains events not in the NOAA one.

Newcomb and McCann (1987) is the only significant modern study of historical earthquakes in the region, bar some papers on individual events, assessed from palaeoseismic data (e.g. Sieh et al. 2004). It deals only with Sumatra and Java, and while some estimated magnitudes are labelled on figures, there is no parametric list of events.

The two volumes of Wichmann (1918, 1922) are limited in time to the period prior to 1878. They present comprehensive descriptive accounts of individual earthquakes in a mixture of languages, including Old Dutch, which makes for problems of reading. The work of Ron Harris's team includes a translation of the work into English, to be published soon (Harris and Major 2012). An advance copy was kindly supplied to the GEH project, and has been used in the preparation of this report. As might be expected from the publication date of Wichmann's work, no parameters are included. Wichmann's sources are many, but include some known to be unreliable, such as Montbéliard (1761). A critical revisiting of original source material is long overdue.

For earlier earthquakes, the NOAA catalogue relies largely on Soloviev and Go (1974), who in turn rely largely on Wichmann (1918, 1922). However, since Soloviev and Go (1974) are concerned only with tsunamigenic earthquakes, they omit other large earthquakes, which are therefore missing from the NOAA list, especially for earlier events where Wichmann is the main secondary source, primary sources not having been consulted.

The following strategy is adopted. All events in sources 1-3 are considered to be potentially equal or greater than 7 Mw. They are compared to each other initially, and then checked against sources 4 and 5 if needed. Where possible, references given by source 2 for individual events are also checked. Additional events are added using Harris and Major (2012) as a guide.

3 Parameters

The following procedures were followed to determine parameters.

3.1 EPICENTRE

For very large earthquakes in subduction zones, epicentre is an almost meaningless concept, particularly for purposes of hazard assessment. What is more meaningful is the midpoint of the rupture. Firstly, this is more likely to approximate to the position of maximum energy radiation, and secondly, from these co-ordinates, together with the rupture length, one can reconstruct the position of the actual rupture, which is the true representation of the localisation of the earthquake, rather than an unrealistic point source.

Indonesia presents a particular problem, in that so much of the seismicity is offshore. Given a coastal observation, one cannot easily tell if the earthquake was far offshore or close in. It is thus easy to underestimate the size of an event that occurred some distance offshore. Historical data tend to reflect places that were important for trade; thus there are a disproportionate number of reports from Ambon and Ternate, as these were significant trading ports, and relatively few from New Guinea. Thus completeness varies at quite short spatial scales.

Assigned epicentres are therefore rather subjective and arbitrary, and should be considered very approximate. An earthquake felt in Ternate, for instance, may have occurred on the Ternate Trough, or on the northern edge of the Halmahera Plate. From a tectonic perspective, large earthquakes affecting Ambon would seem to be more likely to originate on the northern side of Seram, but the historical descriptions, where sufficiently detailed, do tend to suggest a source in the Banda Sea.

In the case of Sumatra, the maps from Newcomb and McCann (1987) area convenient guide to the approximate rupture position. But a comparison with modern seismicity shows that earthquakes may originate on the up-dip edge of the subduction front, or quite close to shore. Some of the aftershocks of the great 16 February 1861 Sumatra earthquake were felt only moderately over about 200 km of coast. If such a pattern arises from a near-shore event, the magnitude is most likely less than 7 Mw; if these events were further out to sea, they could have exceeded 7 Mw.

3.2 MAGNITUDE

Without the use of IDPs, the best guide to magnitude is rupture length, although this cannot be directly observed. It is necessary to assume that the area most strongly shaken indicates the extent of the rupture, as in Newcomb and McCann (1987), which has been used as a guide where possible. In the case of, for instance, the 12 September 2007 Sumatra earthquake, the damaged area was roughly twice the rupture length.

Stirling and Goded (2012), as part of another GEM project (Faulted Earth), reviewed available magnitude/rupture length relationships for different tectonic environments. The recommended equations for use with subduction earthquakes are those of Strasser et al. (2010):

$$Mw = 4.441 + 0.846 \log A \quad (1)$$

and Blaser et al. (2010):

$$\log L = -2.81 + 0.62\ Mw \quad (2)$$

where A is rupture area in km^2 and L is subsurface length in km. Area is harder to estimate than length, so since equation (2) is derived from orthogonal regression it can be inverted to obtain:

$$Mw = 1.61 \log L + 4.53 \quad (3)$$

This can be given a quick test against the earthquake of 26 December 2004 – a rupture length of around 850 km yields 9.2 Mw from equation (3). Given that the magnitudes in this report are provisional values and the rupture lengths are estimates, this is quite acceptable accuracy. It is not practical to estimate rupture lengths from historical data to a resolution of less than 100 km, so this approach really only discriminates great earthquakes.

For some earthquakes, particularly away from the Sunda Arc, there is insufficient information to make any estimate of rupture length. Here the practice has been to assign a minimum likely magnitude of 7.0 Mw to those events that appear to have been heavily damaging. Since the major use of this catalogue will be for hazard calculation, information on major earthquakes will be most important for constraining Gutenberg-Richter curves which will already be to some extent determined by profuse 20th century data. Thus, knowing the number of earthquakes larger than 7 Mw is useful, even if they cannot be graded to finer accuracy. One exception is the earthquake of 1 August 1629; according to Harris and Major (2012), tsunami modelling suggests a magnitude of around 8.8 Mw for this event.

As indicated in the previous section, there is a trade-off between the decision made with regard to epicentre and the magnitude. Some earthquakes may be grossly underestimated because they are known only from distant observations. It is to be stressed that the parameters in this report are to be regarded as highly provisional, pending the results of a much larger, systematic analysis of all the data available, and building on the work of Harris and Major (2012). Such a dedicated project is outside the scope of the present report.

4 Candidate earthquakes

Table 1 is a summary of the initial information available for the study. Each row represents one date on which an earthquake is reported. Each record shows the date, the magnitude reported in the USGS database (if any), the magnitude from the NOAA database (if any), the magnitude from Utsu (2002) (if any), and the magnitude from Newcomb and McCann (1987) (if any). If a source lists the earthquake without a magnitude, an X is shown.

Slight discrepancies in dates are ignored where it is obvious the same earthquake is meant. e.g. discrepancies due to local time and UTC.

Year	Month	Day	USGS	NOAA	Utsu	N&McC	Category	Comment
1629	8	1		X	7.0		B	
1630				X			E	
1657	12			X			B	Should be 1659
1659	11	9		X	X		C	
1673	5	20		X			C	
1673	7	12		X			C	
1673	8	12		X	X		B	
1674	2	12			X		E	
1674	2	17	X	6.8	6.8		A	Should be 1675
1674	5	6		X	6.0		C	
1681	12	11				X	A	
1708	11	28		X	X		C	
1710	3	6		X			B	
1711	9	5		7.0	7.0		C	
1722	10			X			C	
1754	8	18		6.5	X		B	
1754	9	7		X	X		C	
1756	11	3				X	A	
1757	8	24		7.5			C	
1763	9	12		X			B	
1768	6	22		7.5			C	
1770				7.0	7.0	X	A	
1775	4	18		X			C	
1797	2	10		8.0		X	A	
1802	8			X			C	
1814				X			D	
1815	4	11		X	X		E	Volcano
1815	11	22	X	7.0	X		B	
1815	11	27			X		E	Duplication
1816	5	1		X			C	
1818	3	18		7.0	7.0	X	A	
1818	5					X	A	
1818	11	8		8.5	X		B	
1820	12	29	7.5	7.5	7.5		B	
1823	9	9		6.8			C	
1828	12	29	X	X	X		D	
1833	11	24	X	8.3	8.7	8.8	A	
1834	10	10	X	X	X		B	
1835	11	1	X	X	X		B	
1836	3	5		X			D	
1836	11	28		7.5			B	
1837	9	29		7.3			B	
1837	11	28	X	X	X		C	
1840	1	4	X	7.0	7.0	X	B	
1840	2	14		X			B	

1841	11	26		X	X		D	
1841	12	16		6.0			D	
1843	1	5		7.3	7.2	X	A	
1843	2	7		6.0			C	
1845	2	8	X	7.0	7.0		B	
1846	1	25		7.3	7.2		B	
1846	2	14	X		X		E	
1847	11	16	X	X	X		B	
1852	1	9		6.5			B	
1852	11	11		6.8		X	A	
1852	11	19		X			C	
1852	11	25	X	8.3	X		B	
1852	12	24		7.0			B	
1854	1	4		6.0			C	
1854	9	27		X			C	
1855	7	14	X	X	X		B	
1856	3	2	X	X	X		D	
1856	7	25		X			C	
1857	4	17		8.0			C	
1857	5	13		7.0			B	
1857	11	17		X			D	
1857	11	18		X			D	
1858	11	13			7.4		B	
1858	12	13		7.3			E	Same as previous
1859	6	28		7.0	7.0		B	
1859	7	20		X			C	
1859	7	29		7.3	7.2		B	
1859	9	25		6.8	6.7		C	
1859	10	20		X		X	C	
1859	12	17		X			C	
1860	8			X			C	
1860	10	6		X			C	
1861	2	16	X	8.5	8.4	8.5	A	
1861	3	9		7.0	7.0	X	A	
1861	4	7				X	A	
1861	4	26		7.0	7.0	X	A	
1861	4	29				X	A	
1861	6	5			X		C	
1861	6	17		6.8			C	
1861	9	25		6.5	6.5	X	A	
1861	11	19				X	A	
1863	3	16		X			C	
1863	7	31	X	X	X		C	
1864	5	23		7.8	X		B	
1865	7	16	X	X	X		B	
1867	6	10	X	X	X	X	A	

1871	3	2			X		B	
1871	8	25		X			C	
1873				8.0			B	
1875	3	28				X	A	
1875	10	25	X	X	X		B	
1875				7.0			B	
1875	12	13			X		C	Inaccurate date
1876	5	28		6.8			C	
1878	2	4		X			C	
1882	10	10		7.5			B	
1883	8	26	X		X		E	Volcano
1883	8	27	X		X		E	Volcano
1885	4	30		7.3	7.2		B	
1885	7	29		6.8			C	
1885	12	14		X			C	
1886	1	31		X			C	
1887	5	19		X			C	
1888	3	12			X		C	
1888	3	21		X			C	
1889	9	6		8.0	8.0		B	
1889	11	23		6.0			C	
1890	11	23		X			C	
1890	12	12	X	X	X		B	
1891	5	19		X			C	
1891	10	5		7.0			B	
1892	5	17		X	7.5		B	
1892	6	7			X		C	
1892	11	18		7.0			B	
1895	3	6		7.5	7.5		B	
1896	4	18	X	X	X		B	
1896	10	10		6.8			C	
1897	3	15		5.5			C	
1899	1	15		X			C	
1899	9	29	7.8	7.8	7.4		B	
1900	1	10		X			C	
1900	1	14	X	X	X		B	
1900	9	10		6.8	X		C	
1900	9	17		X			C	
1900	10	7	7.8	7.8	7.8		B	
1902	1	24	7.8	7.8	7.8		B	
1903	2	27	8.1	8.1	8.1	7.9	A	
1903	3	30		6.5			C	

Table 1 - Initial earthquake selection and evaluation

The USGS list gives no sources (except "NOAA") and is likely to be the least reliable agency. There are three events that appear only in this, or in USGS and Utsu (2002) only. Two are in

August 1883, and clearly relate to the eruption of Krakatoa, which is listed on the same dates in Ganse and Nelson (1981); one event has somehow been transported to Singapore. The 14 February 1846 earthquake traces back via Ganse and Nelson (1981) to an unreliable US Congress report from 1888, and clearly is a duplication of the 25 January 1846 earthquake. These can therefore be deleted.

The next task is to go through the remaining events and categorise them according to the information available (at least, within the scope of this project). Five categories are defined, as follows:

A Enough information is available to assess parameters using the procedures described in section 3. These are chiefly the earthquakes included in Newcomb and McCann (1987). These are not all necessarily larger than 7 Mw.

B Insufficient information to assess parameters, but these events appear to be ≥ 7.0 Mw. If a magnitude is given by Utsu (2002) or NOAA, this is used (Utsu preferred), otherwise 7.0 Mw is assigned as the "minimum likely" magnitude. The epicentral co-ordinates from Utsu (2002) are used if any, otherwise those from NOAA. In places, co-ordinates are re-assigned where these seem to be obviously at odds with the felt information.

C Insufficient information to assess parameters, but these events appear to be < 7.0 Mw. These events will be dropped from the final catalogue.

D Insufficient information to form any judgement about magnitude. These events will be dropped from the final catalogue.

E Evidence suggests the earthquake is fake (usually a duplication of some other event with a wrong date).

Indications that an earthquake may be > 7 Mw include: high intensity, felt over a substantial area, strong tsunami, and long aftershock sequence. When the only reports are from isolated islands, it can be hard to distinguish between a moderate local shock and a major earthquake some distance offshore. Thus some events may be under-rated. The judgements made between B, C and D are somewhat subjective and should be revisited in a larger project.

While the assumption of 7.0 Mw for events not easily assessable may seem crude, it should be remembered that from the perspective of hazard analysis, the most important thing is anchoring a Gutenberg-Richter curve at the high magnitude end with the number of events > 7, and perhaps 7.5 and 8; the b value will be mostly determined by 20^{th}-21^{st} century seismicity, and discrimination to fractions of a magnitude unit for large historical earthquakes is not a strong concern.

The ratings are shown in Table 1.

Earthquakes can be rated D either because of a complete paucity of evidence, or because the evidence is ambiguous. For example, the earthquake of 1814 (no date) is described as "Earthquake that simultaneously produced a flood wave that penetrated into the Bay of Kupang. A mudslide also took place, through which Pulu Burung, a crag not far from the north shore of the Bay, was made an island" (Wichmann 1918). This is too slender to interpret with confidence and is rated D. Of the earthquake of October 1722, Soloviev and Go (1974), translating Wichmann (1918), report that at Batavia (Djakarta) "There was a strong earthquake. In addition, the water was tossed up in the roadstead as in a "boiling saltern"". This is rated C. The earthquake of 1 August 1629 is rated B on the basis of the very severe tsunami and the fact that it was felt from Bandaneira to Ambon; also, aftershocks continued for some years later.

Not all the events given magnitudes ≥ 7.0 Mw by NOAA or Utsu (2002) seem to justify the values given. For instance, the earthquake of 22 June 1768 is given 7.5 Mw by NOAA, but the only information, from Wichmann (1918), is that there were many shocks in Kambotoros Bay, not far from Cape Saint George at the southern tip of New Ireland. The duration was about 2 minutes. Tremors were also felt on ships riding in the bay, and the sea rose and fell several times (Soloviev and Go 1974). This is rated C here, though the duration of shaking, if accurately reported, could indicate a large event.

As mentioned previously, all the parametric catalogues relying on Soloviev and Go (1974) lack entries for early non-tsunamigenic earthquakes. Several such events, not in Table 1, have been identified from the working files accompanying Harris and Major (2012) and added to the final catalogue. Altogether, thirteen new major earthquakes not previously listed have been added to the catalogue in this way, including five in the 17th century.

5 Notes on new earthquakes

In this section some comments are given on earthquakes not found in any of the agencies used in compiling Table 1. Identification of these is made from Wichmann (1918, 1923) via the agency of Harris and Major (2012). Parameters are assigned to these earthquakes in a very approximate way; then, the parameters given by NOAA and Utsu (2002) are also rather approximate. A systematic assessment of historical earthquake parameters for Indonesia awaits another project.

5.1 12 MAY 1644 AMBON

Harris and Major (2012) give a maximum intensity of 8-9 MMI for this earthquake. It was damaging at Ambon and caused local ground deformation; was described as the strongest ever experienced in the area (Wichmann 1918). A strong aftershock on 17 May was widely felt. Aftershocks continued for two weeks (Harris and Major 2012).

5.2 2 FEBRUARY 1648 FLORES

This earthquake badly damaged Fort Henricus on the north coast of Solor, and was also felt strongly around Larantuka on Flores (Wichmann 1918). Aftershocks continued for over three months (Harris and Major 2012), which suggests a high magnitude.

5.3 17 OCTOBER 1671 SAPARUA

Destruction and heavy damage reported on the island of Saparua; shaking was felt at Ambon, Haruku, and along the south coast of Seram (Wichmann 1918). Aftershocks continued for two months (Harris and Major 2012). There was substantial subsidence associated with this earthquake (Wichmann 1918), which suggests a magnitude as high as 7.5 Mw.

5.4 17 FEBRUARY 1675 AMBON

This earthquakes occurs in the NOAA database with the wrong year (1674) and a magnitude of 6.8. However, in addition to the earthquake being very destructive at Ambon (said to be the strongest ever felt), the effects were widespread across from Buru to western Seram. The shock was weakly perceptible in the Banda Islands (Wichmann 1918). The magnitude must have approached 8 Mw. Aftershocks continued for three months (Harris and Major 2012).

5.5 16 OCTOBER 1683 BANDA

A very destructive earthquake on the Banda Islands (Wichmann 1918) with an aftershock sequence that lasted a year (Harris and Major 2012). With no other localities mentioned, it is hard to gauge the magnitude, but the long aftershock sequence suggests it was large.

5.6 4 JANUARY 1699 BATAVIA

A powerful earthquake in west Java and the southeast parts of Sumatra, which caused damage in the Jakarta (Batavia) area and Lampung province, Sumatra, and was accompanied by triggered landslides and mudflows (Wichmann 1918). On the southwest coast of Sumatra the shaking was weak. Aftershocks continued for over a year (Harris and Major 2012). A tentative magnitude of 7.5 Mw has been assigned, but it could have been larger.

5.7 OCTOBER 1705 AMBON

This was a damaging shock at Ambon, Hitu and Huwamuhal, apparently with liquefaction; shocks continued throughout the month (Wichmann 1918).

5.8 26 JULY 1770 TERNATE

This was considered as a candidate earthquake, given an intensity of 9 MMI by Harris and Major (2012) and an aftershock length of five years. The sequence actually began in April 1770, but the earthquakes are clearly volcanic in nature, and so have not been included in the catalogue.

5.9 30 MARCH 1777 AMBON

Two very strong shocks occurred with a space of four minutes between them; the first was said to have lasted two minutes. There was a very intense aftershock sequence lasting some months. Buildings were damaged and a few collapsed. In the western part of the island there was a major landslip as a result of the earthquake (Wichmann 1918). The reported length of shaking suggests a high magnitude, but there are no accounts from elsewhere.

5.10 22 JANUARY 1780 JAVA

This is clearly one of the largest earthquakes ever to strike Java in historical times, so it is surprising that it is not better known. It was felt over the whole island, more strongly in the west, and also in eastern Sumatra. Houses collapsed in Bogor, Banten and Jakarta (Wichmann 1918). The magnitude must have been at least 8.5 and possibly larger. Harris and Major (2012) list the aftershock sequence as lasting a year.

5.11 14 OCTOBER 1816 BANDA

This sequence started on either 8 October or 11 October, with the strongest shock (said to have lasted two and a half minutes) on 14 October, and aftershocks for the next three months. Banda Neira was devastated, with parts of the island reportedly uninhabitable due to the amount of damage to buildings (Wichmann 1918).

5.12 28 MARCH 1830 AMBON

A damaging shock across the whole island (Wichmann 1918), but no other places are mentioned. Harris and Major (2012) list the aftershock sequence as lasting four months.

5.13 31 OCTOBER 1847 NICOBAR

According to Bilham et al. (2005)

> *The first of the three large historical earthquakes in the Andaman/Nicobar region for which we have information occurred in 1847. Following discussions with Nicobar islanders, Hochstetter (1866) reported a "very remarkable earthquake, which is said to have lasted from 31 October to the 5th of December, 1847, on the Nicobar Islands, at which time earthquakes occurred in Java. ...the description of the earthquake seems trustworthy, as I had myself occasion to observe on Kondul the mountain slips referred to*

> *in the account … No original account of the 1847 earthquake survives, and all secondary accounts appear to derive from Hochstetter's.*

However, Wichmann (1918) was able to draw on accounts from contemporary newspapers (Javasche Courant 23 Feb 1848) for a more detailed account. Houses collapsed, boulders were dislodged, and coastal areas were flooded. Bilham et al. (2005) suggest a minimum magnitude of 7.5, which is adopted here.

5.14 25 APRIL 1855 TERNATE

This earthquake was damaging on Ternate and also at Dodinga on Halmahera (Wichmann 1918). It was followed by a year of aftershocks (Harris and Major 2012). The magnitude has been set at 7 Mw as a minimum, but could have been larger.

5.15 18 AUGUST 1871 BENGKULU

The absence of this event from Newcomb and McCann (1987) and other sources is surprising. It caused houses to collapse in Bengkulu city, and was felt as far east as Java (Wichmann 1923). Reports from Palembang, Lingga and Bogor at 14h 30m and 14h 50m (compared to 14h 16m at Bengkulu) are assumed to refer to the same shock.

6 The catalogue

The final catalogue is presented in Table 2. Times, where given, have all been corrected to UTC, on the assumption that events west of 115^{o} E are 7 hours ahead of UTC, and those to the east are 8 hours ahead. In a number of cases this has involved changes of date from those more commonly given.

A map of events is shown in Figure 1.

Year	Month	Day	Hour	Min	Lat	Lon	Mw
1629	8	1	1	30	-4.30	129.60	8.8
1644	5	12	12		-3.85	128.40	7.0
1648	2	2			-8.40	122.95	7.0
1659	12				-4.20	127.00	7.5
1671	10	17			-3.80	128.70	7.5
1673	8	12	14	15	0.80	127.30	7.0
1675	2	16	23	30	-4.00	127.75	7.9
1681	12	11			-2.20	99.00	7.0
1683	10	16	0		-4.50	130.30	7.0
1699	1	4	18	30	-7.00	105.50	7.5
1705	10				-4.00	127.90	7.0
1710	3	6			-4.53	129.90	7.0
1754	8	18	7	35	-3.50	128.50	7.0
1756	11	3			-4.50	101.40	7.9
1763	9	12	9		-6.70	130.00	7.0
1770					-5.30	102.00	7.0
1777	3	30	1		-4.00	128.00	7.0
1780	1	22	7	39	-8.60	105.50	8.5
1797	2	10	15		-2.00	99.00	8.0
1815	11	22	15		-8.00	115.00	7.0

1816	10	14			-4.60	130.40	7.0
1818	3	18			-4.90	101.60	7.5
1818	11	8	15	15	-7.00	117.00	8.5
1820	12	29	1		-7.00	119.00	7.5
1830	3	28	1		-4.05	128.00	7.0
1833	11	24	13	30	-3.50	100.00	9.0
1834	10	9	22	30	-6.90	107.00	7.0
1835	10	31	19		-3.40	128.10	7.0
1836	11	28	2	30	-8.30	118.70	7.5
1837	9	29	7	15	5.00	94.50	7.3
1840	1	4	6	15	-8.00	110.50	7.0
1840	2	13	16	30	0.80	127.33	7.0
1843	1	5	21	30	1.20	97.80	7.5
1845	2	7	19	30	2.60	122.60	7.0
1846	1	25	1	0	1.40	127.20	7.2
1847	10	31	8	30	6.90	93.00	7.5
1847	11	16	3	18	-6.90	108.30	7.0
1852	1	9	11	9	-6.50	105.50	7.0
1852	11	11	0		1.10	97.70	7.3
1852	11	25	23	50	-4.30	129.50	8.3
1852	12	24	6	15	-5.00	130.50	7.0
1855	4	25			0.80	127.80	7.0
1855	7	14	8		0.70	127.70	7.0
1857	5	13	2	30	-8.00	115.50	7.0
1858	11	13	8		1.00	126.00	7.4
1859	6	28	12	30	1.00	126.50	7.0
1859	7	29	5	30	0.00	125.50	7.2
1861	2	16	12	10	0.90	97.40	8.5
1861	3	9	13		-1.20	98.30	7.0
1861	4	7	9	20	-1.30	98.30	7.0
1861	4	25	23		0.00	97.50	7.5
1861	9	25	6	30	-0.90	98.00	7.0
1864	5	22	16	30	-3.00	135.00	7.8
1865	7	16	19	27	-7.00	110.30	7.0
1867	6	9	21	15	-8.70	111.60	8.0
1871	3	2	12		0.00	128.00	7.0
1871	8	18	13	16	-5.30	102.40	7.6
1873					-5.50	146.00	8.0
1875	3	27	22	30	-9.80	111.50	7.8
1875	10	24	22	50	-6.90	108.30	7.0
1875					-6.00	147.00	7.0
1882	10	10			-4.50	129.90	7.5
1885	4	29	21	53	-2.50	127.50	7.2
1889	9	6			3.10	125.60	8.0
1890	12	12	0	50	-6.40	111.00	7.0
1891	10	5			-9.00	124.00	7.0

1892	5	17	13		0.80	98.00	7.5
1892	11	18			-3.00	127.75	7.0
1895	3	6	8	35	-8.50	150.00	7.5
1896	4	18			-8.30	126.00	7.0
1899	9	29	17	3	-3.00	128.50	7.4
1900	1	11	9	7	-5.00	148.00	7.0
1900	1	14			-6.90	106.80	7.0
1900	9	17	21	45	-5.00	148.00	7.1
1900	10	7	21	4	-2.20	135.50	7.0
1902	1	24	23	27	-8.00	150.00	7.2
1903	2	27	0	43	-6.00	106.00	7.3

Table 2 - The earthquake catalogue

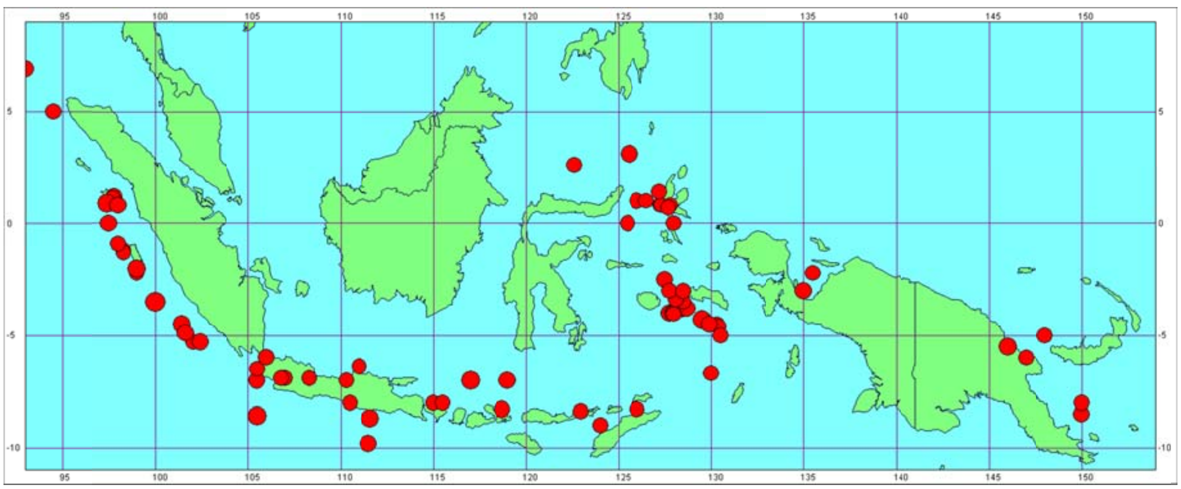

Figure 1 - Large earthquakes in Indonesia to 1903

6.1 EARTHQUAKES AFTER 1900

For earthquakes in the period 1900-1903, early instrumental data is also available, but due to the problems of reading amplitudes from undamped instruments, magnitudes from this period are notoriously unreliable, and locations are also very inaccurate (Kanamori and Abe 1979). Utsu (2002) comments that the magnitudes for events in this period (given in Table 1) are overestimated. Much smaller values have been published by Engdahl and Villasenor (2002), and these are generally followed in Table 2.

Some comments are provided here for the five events in question, to maintain a record of what was done.

11 January 1900 – This earthquake does not appear in Table 1 or in any of the contributing sources. It is not the same as the earthquake of 10 January 1900, rated “C” in Table 1. It is a Rabaul earthquake similar to the shock of 17 September the same year. It has been added to Table 2 using the parameters from Engdahl and Villasenor (2002).

17 September 1900 – This was rated “C” in Table 1, but is assessed as 7.1 Mw by Engdahl and Villasenor (2002). (This is a good instance of how difficult it is to assess earthquakes in New Britain from non-instrumental data).

7 October 1900 – This was given an epicentre at -4.00 140.00 and a magnitude of 7.8 Ms by Gutenberg and Richter (1954). The epicentre is obviously very inaccurate; it is at odds with macroseismic information, which indicates that the shock took place in Cenderawasih Bay. The epicentre has therefore been moved to an arbitrary credible location. Engdahl and Villasenor

(2002) give a magnitude of 6.9 Ms, but retain the epicentre of Gutenberg and Richter (1954). Given the uncertainties, the magnitude listed in Table 2 has been rounded up to 7.0 Mw, rather than lose this event from the catalogue.

24 January 1902 – Magnitude dropped from 7.8 to 7.2 in line with Engdahl and Villasenor (2002).

27 February 1903 – There is general agreement that the magnitude of Gutenberg and Richter (1954) is overestimated at 8.1; also, their epicentre is mislocated considerably too far south (Newcomb and McCann 1987). Utsu (2002) gives a magnitude of 7.4, and Engdahl and Villasenor (2002) give 7.3 Mw, which is adopted here. However, they still cite Gutenberg and Richter's (1954) wrong epicentre. The epicentre given here has been moved two degrees northwards, in line with Newcomb and McCann (1987). Both the revised location and magnitude are in good agreement with macroseismic data.

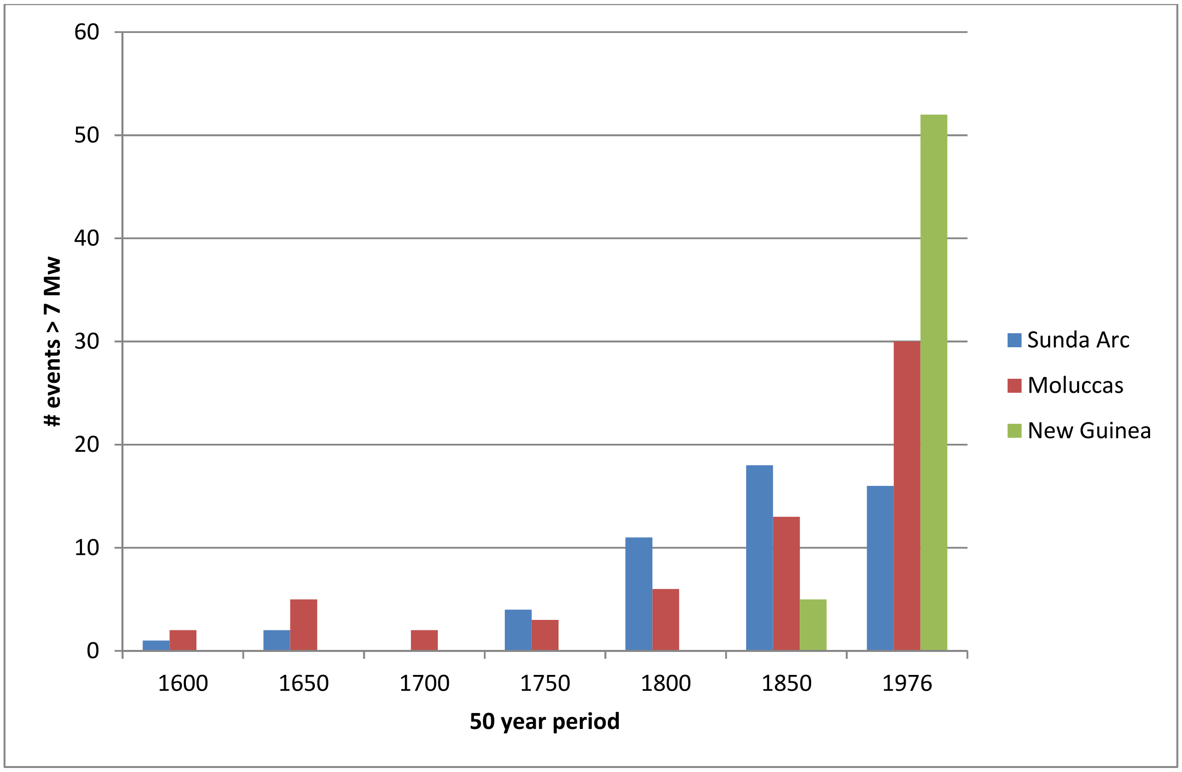

Figure 2 - Comparative numbers for 50 year periods

6.2 COMPLETENESS

How complete is the catalogue? The answer is: not very. For the purposes of analysis, the area is divided into three: the Sunda Arc (Sumatra to Timor), the Moluccas (including the Banda Sea and Sulawesi) and New Guinea (including New Britain). The number of events in the catalogue (i.e. 7.0 Mw or greater) was counted for successive 50-year periods beginning with 1601-1650. The results are shown in Figure 2 (for neatness, 1601-1650 is labelled 1600, etc). Analysis for larger magnitudes (7.5 or 8 Mw) has not been attempted owing to the episodic nature of such events.

The numbers are compared with modern data by taking PDE data from 1976-2000 (thus predating the intensive Sumatra seismicity after 2004), counting the events and doubling the number.

For the Sunda Arc, the catalogue has comparable numbers to the 1976-2000 data for the period 1851-1900, and quite possibly the catalogue has acceptable completeness back to 1800. For the other regions the catalogue is very incomplete.

There are three principle reasons for this. One is the difficulty of dealing with intermediate and deep focus events from historical data. When the modern data was restricted to crustal events, the total for the Moluccas dropped from 30 to 22, and for New Guinea from 52 to 26.

The second is the concentration of reports from important trading centres, and the relative lack of information from areas such as Sulawesi and New Guinea.

The third is the difficulty, mentioned previously, of recognising large offshore events from very limited historical data. The two volumes of Wichmann contain reports of earthquakes in New Britain, many of which are probably larger than 7 Mw, and which would go some way towards making up the shortfall shown in Figure 2. The problem is that most of these reports do not give details that allow one to identify the earthquakes as major events with any degree of assurance. A thorough, systematic processing of Wichmann's work, combined with examination of colonial archives in Europe, may in time improve the situation, but such a labour is outside the scope of this report.

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