POPULATION HISTORY IN A DANGEROUS ENVIRONMENT: HOW IMPORTANT MAY NATURAL DISASTERS HAVE BEEN?

Anthony Reid

Australian National University

ABSTRACT

The longer the time-depth considered, the more human history is dependent on the beneficence of the planet we inhabit. The disastrous Aceh tsunami of 2004 stimulated geological research which has revealed similar mega-tsunamis resulting from earthquakes of 9.0 magnitude or more every few centuries in the past. Even more destructive to civilization and agriculture are the massive volcanic eruptions such as Tembora (1815), which caused crop failures around the world, let alone in under-researched Indonesia itself. The new geological research strengthens a growing sense of Indonesian population history as one unusually exposed to the disruptive rhythm of the planet. In periods of relative quiescence on the 'ring of fire', such as the twentieth century, a benign climate and fertile volcanic soils can produce rapid population growth and development. But rather than forming a constant, this pattern appears to have been interrupted by periodic disasters. Interdisciplinary research is desperately needed to locate past traumas, and relate them to what we know of the historical record. It may also reveal, on the positive side, that the Archipelago's celebrated human and biological diversity owes something to the periodic disruption to agriculture-based civilization.

Keywords: Natural disaster, Volcanic, Population

INTRODUCTION

Since the sequence of disasters between the Aceh-Nias tsunami of December 2004 and the Merapi eruption of October 2010, attention is at last being paid to Indonesia's past record of disasters. Whereas this had been a scientific backwater, many earth scientists are now seeing the Sunda megathrust as one of the key parts of the world to study tectonic subduction, since the upheavals are relatively regular, and dramatically extreme in their impact (Perkins 2008).

We now know that ruptures in the earth's crust occur with necessary regularity, and that the bigger events every few centuries have enormous impacts not only on Indonesia, but on the planet as a whole. Our politically focused histories look woefully inadequate to explain this pattern. The scientists use the data of historians when they can, though in Southeast Asia we have not been particularly helpful to them. A comprehensive record began to be available for the whole planet only once the seismograph was invented, around 1900, and long after that descriptions of the effects of seismic movements on human societies remained underreported in Indonesia. Before 1900 our understanding is above all dependent on written records of observers, although the ring of fire around the Pacific where the periodic pattern should be clearest is, except for Japan, poorly provided with historical records before 1600.

The geologists have done a little better than the historians at recording data for Southeast Asia, but this region remains badly underreported in comparison with other parts of the ring of fire. The US National Geophysical Data Center records only four tsunamis in Sumatra before 1800, because they damaged the Dutch pepper-posts, and none in Java where the endangered south coast was then of no interest to the Dutch. By contrast 29 Indonesian tsunamis have been recorded in the 23 years since 1990, including nine massive ones each killing over 100 people, two of them in Java. The missing earlier records need to be reconstructed by patient comparison of the ignored fragments of data in the historical sources with physical evidence on the ground.

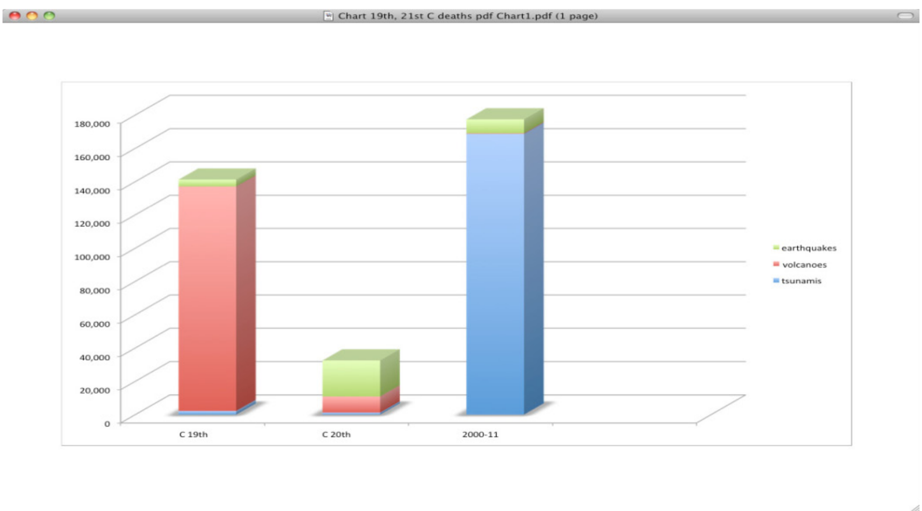
Volcanic eruptions were more spectacular and therefore slightly better recorded, though the record before Krakatau (1883) is far more poorly documented than elsewhere. The Smithsonian volcanism database shows that 25 per cent of the world's major eruptions, measured in terms of Volcanic Explosivity Index (VEI) at four or more, since 1982 have been in Indonesia. The further we go back in time, the more Indonesia drops off the data bases. Out of more than 500 probable major eruptions dated by various systems between 10,000 BCE and 1500 CE, only five, or one per cent, are proposed very questionably for Indonesia (Smithsonian GVP). Almost everything remains to be done. No destructive (VEI 4+) Southeast Asian eruptions before 1500 have been documented to the more exacting standards of the National Geophysical Data Centre, although 35 are acknowledged elsewhere (NOAA). Yet Indonesia has many more calderas than any other country big enough to have been the source of one or more global years without normal sunlight (Keys 2000: 372-374).

Southeast Asian sources themselves were surprisingly little concerned to record natural disasters, except insofar as volcanic eruptions served as portents for human events. They were relatively little affected by earthquakes because of the light and flexible construction of their buildings, and by tsunamis because earlier generations had learned, no doubt painfully, how devastating they could be. The tsunami-prone coasts of Nias, Mentawai, western Sumatra and southern Java were relatively deserted before 1800, and only a careful re-reading of sources begins to show that past disasters played a role in this choice. The people of Nias, probably the most vulnerable to tsunamis of all complex Indonesian societies, regularly made offerings to the god of the sea and of earthquakes, recognizing the connections between big earthquakes and tsunamis. They threw gold and other offerings into the sea and into the cracks appearing with earthquakes (Schröder 1917: 415-416, 514). Until sea-based Dutch infrastructure arrived in the second half of the nineteenth century, however, the Nias people avoided building homes on the endangered coast, fished primarily in fresh-water rivers, and built their villages on hilltops where possible (Gruber no date).One of their origin-myths shows the creator god sending his sons to people the earth. The first was sent to the south which began to submerge beneath the sea because of his weight, so he sent the second to the north. When that too began to submerge with the centre rising upward he sent the last two sons to the centre, and balance was restored (Hämmerle 1999: 44; Schröder 1917: 515-516). Mentawai islanders also built their villages away from the coast. Their mythology had the lower tier of the cosmos, the underworld, as the abode of the earthquake god, who had to be propitiated with the erection of each house (Schefold 1988: 73-75; Loeb 1935: 134, 161).

INDONESIA TAKES SHAPE IN A QUIET CENTURY

Until the round of disasters in Sumatra and Java since 2004, neither historians nor scientists had given the past record the attention it deserved. After the Krakatau eruption of 1883 there had been more than a century of relative geological calm, with a death toll that by hindsight appears uncannily low (Figure 1). In the quiet time, geologically speaking, between 1885 and 2000,the Indonesian population grew from about 25 million to 205 million, and its urban, predominately coastal population from little over one million to 90 million. A large, modern state was created, its infrastructure built with little consideration of the geological dangers, with urban centres at Banda Aceh, Padang, Bengkulu, Cilacap and Ambon all directly facing some of the world's most dangerous subduction zones. In the cities, moreover, building was predominately of poor-quality brick construction, so that the series of earthquakes since 2000 has produced much greater carnage than previously. Padang's 1833 earthquake had been much bigger than that of 2009 (7.6 magnitude), and was accompanied by a major tsunami, but the population of the West Sumatran littoral was then less than 80,000 compared with over two million today. Whereas the 1833 toll was a few hundred, that of 2009 accounted for over 1,000 dead with 135,000 homes destroyed and 1.25 million people affected.

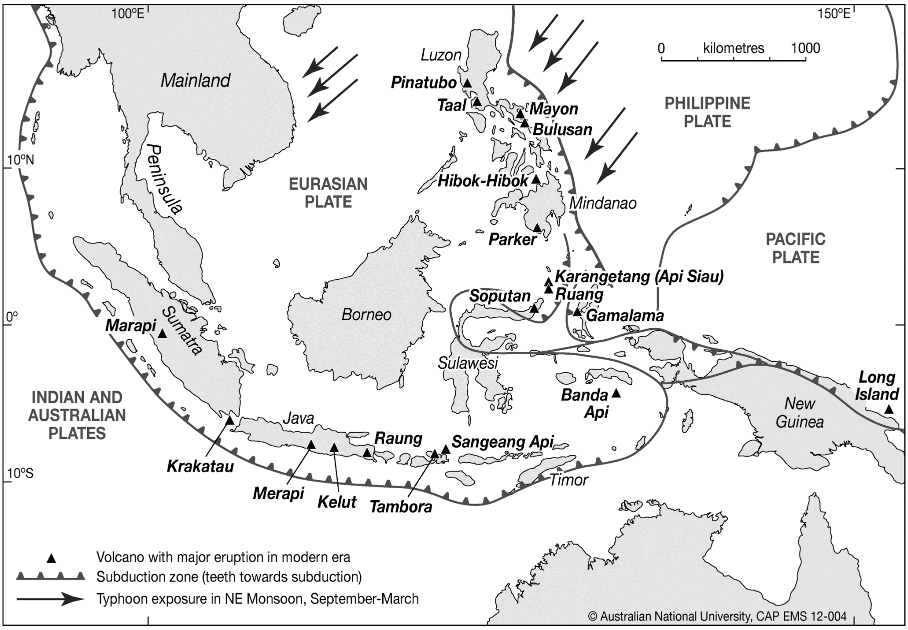
Figure 1
Deaths in Indonesia from 'natural' (tectonic) disasters by century[1]



Map 1

1 The data on which this graph is based was assembled and presented in a separate paper (Reid forthcoming). Deaths from volcanic eruptions would have to be moved substantially upward if based on census figures as done below.

Major natural threats to Southeast Asia



Because of the relatively low number of casualties from Indonesia's natural disasters during the twentieth century, compared to the very high numbers of casualties of political conflict, it is not surprising that historians should have focused on the political events, most of them state-sponsored. Figure 1 shows the low human cost of nature's ravages in the twentieth century, even before allowing for the great underestimates for nineteenth-century deaths due to sketchy knowledge of, or interest in the most vulnerable areas outside Java. Tambora and Krakatau, but not the 'routine' earthquakes and tsunamis, forced themselves into the records. Elsewhere I demonstrate that the deaths directly attributed to political conflict in the twentieth century outnumbered those caused by geological spasms by about 30 to 1(Reid forthcoming). The reversal since 2000 has been dramatic, partly because of the extraordinary death toll of the 2004 tsunami. Natural disasters outnumbered conflict deaths 17 to 1 in the first decade of the twenty-first century. In fact the political killing of the democratic transition finally stopped about 2002, so that the ratio in the decade since then is more like 100 to 1 in favour of natural disasters. Steven Pinker (2011) has shown that violent deaths from human conflict have in fact declined dramatically in most places as a proportion of total deaths,[2] even if the Indonesian figures look high in the mid-twentieth century as the world-system readjusted from empires to nation-states. Since 1980 Southeast Asia has joined the global downward trend for violent conflict deaths. Natural disasters on the other hand had already caused four times as many deaths in Indonesia in the first decade of the twenty-first than the whole of the twentieth century, and will certainly cause many more.

ESTIMATING THE POPULATION EFFECTS OF MODERN ERUPTIONS

There are puzzles about the population history of the tectonically-threatened island arc from Sumatra to Luzon, and especially its volcanic jewel, Java (Map 1). The entire region had population densities well below the rest of humid Asia in the early 1800s when population began to be assessed accurately, even though humans had flourished in this region for longer than in most of Asia, surviving the ice ages as was not possible further north. Its environmental conditions were congenial to human life, and its volcanic soils and humid climate were favourable to agriculture, which had been practiced there for at least 5,000 years. This was demonstrated by the astonishing growth of population of the two main volcanic rice-baskets in the 'mild' period between 1835 and 2000. Java grew from about six to 125 million, achieving one of the highest rural population densities in the world. In general demographers have either struggled to show the earliest estimates must have been much too low, or explained extremely low growth rates prior to the colonial peace by a pattern of disease and small-scale warfare, as indeed did I (Reid 1987). The pattern of periodic mega-disasters, particularly in the form of volcanic eruptions affecting agriculture, must now be built into this explanation. Volcanic eruptions alternately enabled intense agricultural production through the rich volcanic soils, and destroyed it by ash deposits and the blocking out of sunlight. But so little of the destructive power was displayed in the relatively calm period after 1835 that even the historians have neglected this likelihood.

The Tambora eruption of April 1815 has attracted more attention than other Southeast Asian disasters, once it was discovered to have been the cause of the notorious 'year without summer' in Western Europe and North America in 1816. Besides leaving a substantial ash deposit in the ice caps of both

[2] See further Pinker 2011.

polar regions, it lowered temperatures in the northern hemisphere and caused disastrous crop failures and freakish weather (Oppenheimer 2003). Its effects in Indonesia itself were probably the most acute; we know for example that the global climate-affecting Laki eruptions in Iceland in 1783 also killed 20-25 per cent of Iceland's population and most of its livestock through the deposit of hydrogen fluoride and sulphur dioxide. Local effects of southeast Asian mega-eruptions in Southeast Asia, however, are scarcely beginning to be investigated. Most scholarly interest has been devoted to the effects of Indonesia's eruptions on global climate, notably the lowering of temperatures in the northern hemisphere (Mass & Portman 1989; Briffa *et al.* 1998). By looking at population figures here, I hope to suggest the dimensions of damage to the nearby social structure of these mega-eruptions, though much more research is needed to understand the mechanisms by which this occurred.

Those directly killed in 1815 by the explosion of gases and lava flows were mainly on the Tambora Peninsula formed by the mountain on the island of Sumbawa, where the explosion killed virtually everybody, around 11,000 people. The Tambora language, a word-list of which had been collected by Raffles before the eruption, was wiped out, eliminating what is now understood to have been by far the most westerly survival of a Papuan-type (non-Austronesian) language (Donahue 2007). Figures between 60,000 and 90,000 are often cited for the numbers who died from hunger and disease in the remainder of the island of Sumbawa, and in Lombok, Bali and East Java to its west, as agriculture was destroyed by ash deposits and lack of sunlight. Such estimates are necessarily extremely speculative in the absence of accurate population data for the period. Harvests in Bali (the best-documented) were drastically affected for the next four years. The effect was worsened by a severe earthquake in Bali in November of the same year, which caused the crater lake of Mount Pangilingan to burst its banks, destroying seventeen villages in North Bali and killing an estimated 10,000 people. The devastated population was then assailed by infestations of rats which consumed much of the little food left. A Dutch visitor to Bali in 1818 counted 34 corpses lying beside the 25 km track between Badung and Gianyar, having presumably failed to survive the desperate walk in search of food. The same Dutch observer pointed out, 'The lords are dirt-poor, while the people suffer great deprivations and often go hungry'. Only after 10-15 years of misery did the ecological curse turn again to a blessing as the nutrients in the ash were absorbed to fertilise

Bali's soils (Van der Kraan 1993: 107-110 [quotation on p. 109]; see also Creese 1997: 356).

Table 1
Population Effects of Krakatau Eruption May 1883 on Two Java Residencies

	BANTEN			BATAVIA		
	population	if at 1.6%	Missing	popula-tion	if at 1.6%	missing
1882	560,660			838,015		
1883	538,186	569,631	31,445	835,943	851,423	15,480
1884	541,216	578,744	37,528	863,796	865,046	1,250
1885	528,696	588,005	59,309	879,801	878,887	-
1886	544,321	597,413	53,092	926,892	892,949	-
1887	561,003	606,972	45,969	937,289	907236	-

Source: Boomgaard & Gooszen 1991: 116.

At the time of the Krakatau eruption in May 1883 population and production figures were a little better, though still inadequate to determine the full effects of the eruption. The closest regencies to Krakatau, Banten and Batavia in Java and Lampung in Sumatra, all lost a significant population in the years immediately after the eruption, though I am not aware of any specific study of these effects. Table 1 gives official figures for the two Java residencies compared with the expected growth rate for Java of the period, estimated by Boomgaard and Gooszen (1991) as 1.6 per cent per year.

Figures for Lampung are available at five-year intervals, showing a population of 125,400 in 1880 having dropped to 118,550 in 1885, but recovering to 127,300 in 1890. Allowing for expected population growth, which was at 1.9 per cent per year when figures are available for 1900-1905, the population should have grown to 137,774 in 1885 and 151,370 in 1990 (Boomgaard & Gooszen 1991: 44, 224).The missing population would then be 19,224 in 1885 and 24,070 in 1890. Unfortunately there are no such reliable figures for Palembang, Jambi and Bengkulu, which were very likely also affected by the cloud of ash. Officials noted that 'fever' was a particularly virulent killer in 1883 and 1884, 'when large numbers of people were rendered homeless by the eruption of Krakatau', and that this affected not only Banten and Batavia, but also Banyumas and Bagelen further east (Boomgaard & Gooszen 1991: 56). Bagelen's population, indeed, was recorded as suffering an absolute drop from1,287,938 in 1883 to 1,268,966 in 1886 (Boomgaard & Gooszen 1991: 116), which represents a loss of 62,815 inhabitants from the 1,350,753 which would have been reached if Java's overall growth rate of 1.6 per cent per year had occurred. Since the intervening residencies of Priangan and Banyumas did not show such a clear effect, however, we should be cautious in attributing all this loss to the impact of Krakatau.

Nevertheless the longer-term effects of the eruption on mortality through crop failure, starvation, lack of clean water and attendant diseases, were certainly greater than the 30,000 conventionally attributed to Krakatau, mainly as victims of its tsunami. A more realistic estimate for the years 1883/85 would be in excess of 100,000.

Although I have not located rice crop yields in these years, Pierre van der Eng's figures make clear that there was a significant drop in the availability of rice per capita in Java as a whole between 1880 and 1890, with the sharpest drop in 1883. Between 1881/85 and 1886/90 the drop he calculated was 11.4 per cent in rice availability per capita, although only 6 per cent if adding all the five other staple food crops of Java (van der Eng 2000: 599, 616). Nutrition levels and even measured heights of sample populations reached their nadir in Java between 1870 and 1910, Javanese appear to have been about two centimeters shorter in the 1880s than in the 1850s, as well as more poorly nourished (Baten, Stegl & van der Eng 2013). van der Eng and his colleagues already drew attention to the Krakatau eruption as one of contributing factors to this apparent nadir in the living conditions of the inhabitants of Java.

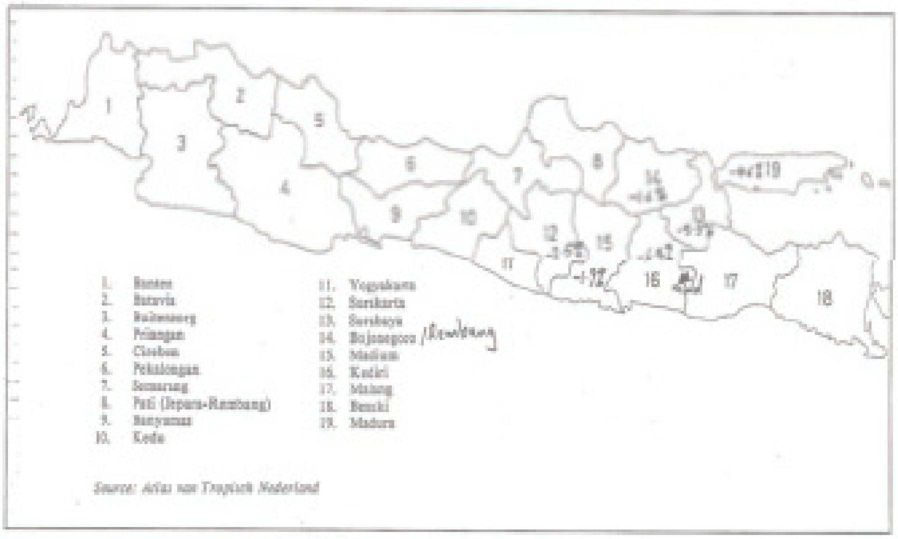
Population data is better for the twentieth century, when the most lethal eruption of a comparatively quiet century was that of Kelud on 19/20 May 1919. The immediate deaths from pyroclastic flows and the bursting of its crater lake were reported as 5,110, primarily in Blitar (Kediri, East Java) to the immediate southwest of the volcano. The deaths resulting from starvation, disease and dislocation were far greater, particularly in the districts to the immediate west and northwest of the mountain, the direction in which prevailing winds carry the ash deposit. This means the regencies of Kediri, Surabaya, Rembang, Madura and even Surakarta and Semarang, all of which showed a substantial population deficit in 1919 and 1920, even from the low point created by the influenza epidemic in 1918, when Java's population was reported as 200,000 below what it had been in 1917. In 1919 it was listed as 249,000 lower again, although the virulent stage of the influenza epidemic was over (Boomgaard & Gooszens 1991: 119).

Siddarth Chandra has made some sophisticated calculations on the population figures of this period to show that, given the expected population increase of 1.75 per cent per annum in this period, Java in fact lost over four million people to the influenza epidemic, rather than the 1.5 million for all Indonesia mentioned in the literature. Chandra does not consider other contributing factors to the high mortality of this period, as those on the ground at the time were obliged to do (Chandra 2013).

Table 2
Missing Population After the Influenza Crisis Year of 1918

	1918	1920	if at 1.75%	missing	missing %
All Java	33,376,545	34,433,476	34,554,945	121,469	0.35%
Kediri	2,062,710	1,990,538	2,135,536	144,998	6.79%
Surabaya	2,445,082	2,396,520	2,531,409	134,888	5.33%
Madura	1,758,056	1,736,651	1,820,126	83,475	4.59%
Madiun	1,561,099	1,586,008	1,616,215	30,207	1.87%
Surakarta	2,010,368	2,029,843	2,081,346	51,503	2.47%
Rembang	1,611,420	1,641,859	1,668,313	26,454	1.59%

Map 3
Administrative division of Java, c. 1935



The particularly high mortality in the residencies in Kelud's 'shadow' in 1919 and 1920, however, makes clear that the effect of the eruption was very great indeed, whether from the deposit of ash and suphorous acids, or reduced sunlight. Table 2 shows that the missing population in the crisis years 1919 and 1920, after the worst impact of the influenza in 1918, was in almost exact proportion to the distance from Mount Kelud in the ash shadow of the eruption. This unexpectedly large discrepancy between the residencies in the immediate shadow of Kelud is a striking demonstration of the indirect effects on health and mortality of major volcanic eruptions. It demonstrates that, whereas the rest of Java was recovering in 1919 and 1920 from the severe impact of the influenza epidemic in 1918, the areas most affected by the Kelud eruption continued to lose population even in absolute terms. That the adjacent residencies should lose in excess of five per cent of their expected population, and that the total loss exceeded half a million, shows convincingly that we need to revisit the larger eruptions in the era before accurate population counts with the expectation that the effect on population will be very great.

The eruption of Mount Pinatubo in 1991 (with a second 1992), the most recent in the region to reach 5 on the VEI scale, revealed how modern monitoring and timely evacuation can reduce deaths from a mega-eruption, especially when it behaves as co-operatively as Pinatubo in a gradually escalating series of warning events. 60,000 people were evacuated in the month before the eruption, including 14,000 from the US Air Force base at Tarlac, 15 km from the volcano, which was never re-established. It was estimated that 20,000 of these would have died immediately from the eruption, though only 700 did so, mostly from collapsing roves from the weight of ash. The recent date of this disaster provides better documentation of the effects on agriculture. Some 2,000 square kilometres were covered with ash at least 10 cm in depth, and 7,000 square km at least 1 cm. Two years after the event, it was estimated that 2.1 million people were affected and 8,000 houses destroyed, mostly in Zambales, Pampanga and Tarlac. 81,900 hectares of rice land were destroyed (compared with 15,000 hectares for Kelud in 1919 ("Kelud Volcano"), at a cost in lost production of 351 million pesos. 779,000 head of livestock and poultry were believed to have died, making a further loss of 203 million pesos. The Department of Agriculture in Central Luzon then (1993) calculated total losses from lahars and ash deposit as 1.5 billion pesos ($55 million) (Mercado *et al.* 1993; Pappas 2011).

OTHER LIKELY VOLCANIC CONSEQUENCES

Although Java was far better known to the Dutch than the other Indonesian islands in the eighteenth and nineteenth centuries, we still know too little about volcanic and other disasters even there before Krakatau (1883) captured the world's attention. When relatively detailed population surveys began to be made by Raffles around 1813 and the returning Dutch from 1820, the low population of two areas stands out – the Sundanese area of Parahyangan (West Java) and the eastern salient of Java. Boomgaard shows population densities for 1820 of ten per square km for the whole of Parahyangan (covering fully half of West Java), nine for Krawang to its north and only four for Banyuwangi, the easternmost of Java's residencies, against an overall density for Java of 43 (Boomgaard 1989: 75).The Tasikmalaya area of West Java was devastated in 1822 by the lava flow from a big eruption of Mount Galunggung (VEI 5), recorded as having directly killed 4011 people (Bronto 1989; Smithsonian GVP). The earliest European accounts in the eighteenth century judged it a sparsely peopled place of 'simple and uneducated mountaineers'. Raffles noted formerly cultivated areas of Parahyangan abandoned in his (Raffles 1829: I, 71-72, quotation on p. 399).

These poorly populated areas are for the same reason among the most fertile in Java, with among the highest productivity per hectare in Java. Their populations increased particularly dramatically during the geologically quieter times after 1830, even though the 1883 Krakatau eruption again depopulated the south-western corner. Today Sundanese-speaking West Java (minus Jakarta and Banten) is Indonesia's most populous province with the densest population (except for the city-provinces) of 1,235 per square km.

In the easternmost salient of Java (the *Oosthoek* to the Dutch), the almost total depopulation of Banyuwangi by 1820 is usually attributed to the prolonged warfare over the area between Hindu Balinese and Muslim Mataram, with the Dutch East India Company (Vereenigde Oost-Indische Compagnie, VOC) adding a nasty kind of scorched-earth policy when they intervened after taking over Mataram's claims in 1734. But it is likely that the eruption of Tambora in 1815, and of the Oosthoek's own unusually active volcanoes, also played a significant role (Kumar 1979: 191). Mount Ijen possesses the largest caldera in Java at 20km, and the world's largest acidic crater lake which confers both benefits of sulphur deposits and great dangers of spillage in eruptions that occurred in 1797 and 1817. Nearby Mount Raung has erupted 43 times since 1880, but its earlier eruptions were more severe, causing numerous deaths in 1638, 1730, and January 1817. There is a suggestion of the memory of past devastations of rice agriculture in a report by Van Ryck on the peoples living on the slopes of Mount Bromo [Brama] in East Java in 1785. While he admired their uprightness and 'peacability', Van den Berg found them astonishingly 'blind and superstitious' when it came to rice agriculture. 'On the whole of (Mount) Brama, and the nearby Tengger and Tjierische ranges, they will plant no padi, and will also stamp husk no padi into rice, in the belief that to do so would cause the greatest misfortune to be visited on their land and people' (Van Ryck 1814: 2-3).[3]

[3] Eruptions of the Tengger Caldera area are thought very uncertainly to have occurred in 1767, 1775, 1804 and 1815.

VOLCANOES AND HINDU-BUDDHIST CIVILIZATION

West Java's discontinuity is particularly striking, as it was the site of the earliest inscriptions in Java, evidence for some kind of polity named Tarumanegara on the coast as early as the fifth century. Javanese legends acknowledge the western area as the source of ancient legitimacy associated with the Baron Sakundar myth as well as that of Ratu Kidul (of whom more below) (Ricklefs 1974; Pigeaud 1968: II, 249). David Keys has assembled plausible evidence for a massive eruption in westernmost Java (though not necessarily an earlier Krakatau event as he proposes), causing the major global cooling now well documented forthe year 535 (Keys 2000: 374-378). He links this to a Javanese tradition, recorded in the nineteenth-century *Pustaka Raja Purwa*, that Sumatra and Java were one island until a vast eruption separated them early in the Common Era. All this means that we should take seriously the likelihood that it was an eruption that moved the centre of Javanese civilization from west to central Java in the sixth or seventh century. West Java appears to have flourished again in the ninth to eleventh centuries, with its Sunda kingdom initially having relations with the first Mataram in central Java. According to the *Carita Parahiyangan*, a manuscript probably of the late seventeenth century found in Cirebon, the rule of Sri Jayabhupati, given as 1030-1042/3 (*Saka* 952-64), appears to have been particularly successful. In 1042/3 (*Saka* year 964), however, 'clouds of ash overshadowed the kingdom of Sunda', the king mysteriously departed and the glorious times were over (Abdurrachman & Ekajati 1991: 23-28, quotation on p. 28).

Could the same eruption have had a role in the better-known collapse of the early Mataram civilization of Central Java, which built the magnificent temples of Borobudur (Buddhist) and Prambanan (Saivite) among many others in the period 600-900 CE. It has been conventional in Java to point to an eruption of Merapi in about 1000 CE as the cause, based on hypotheses going back to IJzerman in 1891, repeated by Dutch geologists such as Van Bemmelen (IJzerman 1891; Van Bemmelen 1949). Recent research summarized by Newhall *et al*. and Jan Christie has replaced this simple hypothesis with evidence of a number of major eruptions that contributed to the absence of dated inscriptions after 928 CE. There are three distinct layers of volcanic ash in the Borobudur area, but the thickest of up to half a meter clearly put an end to occupation of the ninth and early tenth centuries. To the south of Merapi around modern Yogyakarta, perhaps the densest area of settlement then as now, several layers of lava in quick succession appear to have buried temples. Recently excavated temples, such as Sambisari and Kedulan were below seven meters of lava. In the ninth and tenth centuries the centre of activity shifted to East Java, and surviving inscriptions of this period were increasingly concerned to propitiate local ancestor-spirits associated with the volcanoes rather than Indic deities. A number of successive eruptions may be responsible (Newhall *et al.*2000; Wisseman Christie forthcoming). We should now look beyond Merapi for a fuller explanation of why this fertile central Java region fell silent for six centuries. A bigger eruption from a more distant volcano, less given to regular small eruptions than Merapi, may have caused the crops to fail for long enough to put an end to civilization.

The earliest Javanese chronicle with reliable dates for events, such as volcanoes, is the East Javanese *Pararaton*, probably compiled in the late fifteenth or sixteenth centuries, describing much of the history of Majapahit. It clearly regarded eruptions as important and listed nine of them between 1311 and 1481, the last of which ends the chronicle (Phalgunadi 1996). One of these may in fact have buried Candi Sambisari in 6.5 meters of debris from which it was recently excavated, since there is evidence that it was unburied long enough for Muslim forces to plunder it (Newhall *et al.* 2000: 45).The established historiography has given its attention almost exclusively to the challenge of Islam and its trade-based *pesisir* cities to Javanese civilization in the decades before and after 1500, but natural disasters are highly likely to have played a role.

Into our still murky understanding of the collapse of Hindu-Buddhist civilization in Java the date 1258 AD comes as something of a surprise. This has now been confidently established by the climatologists as the date of ‘the world’s largest volcanic eruption of the past millennium’ based on Arctic and Antarctic ice cores, and therefore definitely with a tropical source. It suddenly darkened skies and dropped temperatures in England, and caused crop failures and disease in much of Europe and the Middle East (Stothers 2000; Emile-Geay *et al.* 2008). The careful dating of a Museum of London Archaeology team recently showed it to have been responsible for the mass burial of thousands of victims of hunger or disease in the Spital fields cemetery of London (Hilts 2012). An international and interdisciplinary team that investigated the chemical composition of rocks ejected by leading suspect volcanoes for a match with that of the ash deposits believes it has found the source in a massive eruption at Mount Rinjani in Lombok (Witze 2012).[4]

A date of 1257 (likeliest for effects around the world in 1258) had not suggested itself to the historians of Java, though it is not incompatible with the little we know of the thirteenth century. The rise of Singhasari's power in East Java under Kertanegara from 1268 is reasonably secure from later chronicles, but there is no continuous history stretching before that, back to the legendary mighty founder Ken Arok, who reputedly died in 1227. In Bali, which would certainly have had its agriculture devastated by such a massive explosion in adjacent Lombok, the slim evidence we have also seems compatible with the occurrence of a catastrophe around the middle of the thirteenth century. The dated inscriptions in Bali are relatively numerous from 911 to 1204 CE, with 135 dated inscriptions, or datable by context, falling in those three centuries. There is however only one more inscription in almost a century between 1204 and 1296, with 15 further inscriptions then being produced in the years before the Javanese invasion of Bali in 1343. That one anomaly is the Bulian B inscription, mentioning a ruler or chief named Adidewa Lancana and a date. This date was read by Van Stein Callenfels as *Saka* (Java/Bali calendar) 1172 = 1250CE, but by R. Goris as *Saka* 1182 = 1260CE (Goris 1954: I, 41-42, II, 345-346; Robson 1978). If the former were correct, it would mean a period of 38 silent years following a Rinjani eruption in 1257; if the latter, then there is a problem in explaining Bulian B being written without mentioning a terrible disaster overcoming the land only two years earlier.

SURVIVAL OF DIVERSITY

Even though chroniclers of the time may have been unaware of the connection, therefore, the most numerous fatalities and disruptions to civilization in earlier mega-eruptions would have arisen not from the dramatic immediate victims of gasses and lava, but from the failure of crops as a result of the ash deposits, acid rain and lack of sunlight over a period of several years. In attempting to understand the longer-term effects of this extremely dangerous environment, a first step is to recognize that densely-settled wet-rice (*sawah*) farmers were the

[4] In a personal communication (24 April 2013), the French geographer leading this team, Franck Lavigne, specified that the evidence was strong for Rinjani as the source of a 1257 eruption, although the paper had not at that stage been published,.

most vulnerable because of their reliance on a single crop delicately adjusted to climate and environment. Their vulnerability to disasters helps explain Southeast Asia's remarkable human and biological diversity, particularly evident in the most exposed arc of tectonic subduction around the region's southern and eastern rim.

The most remarkable human survival in the region is the diminutive 'hobbit', *Homo floresiensis,* discovered in 2003 to have survived as recently as 12,000 years ago, and thus long co-existing with *Homo sapiens*. The find was in Flores, easterly neighbour of Sumbawa and itself one long volcanic spine including eight active volcanoes still causing significant damage in the twentieth century. The dominant Flores population today itself has more visible genetic links with older Australo-Melanesian inhabitants (pre-Austronesian and closer to Australian and New Guinea populations) than elsewhere, and has vivid memories of different 'wild men' surviving up to a few generations ago (Forth 2006). Since the sea crossing to Flores from other islands is not difficult, the likelihood is that Austronesian agriculturalists repeatedly colonized the island, but were checked from taking over as fully as elsewhere by the effects of major eruptions (and tsunamis on the coast).

The Philippine islands were also occupied by a small, though presumably very long-standing, Austronesian agricultural population at the Spanish arrival in the sixteenth century, as well as by darker Australo-Melanesian hunter-gatherers, estimated to be still 10 per cent of the population in 1600. The Spanish called these people *negros* or *negritos*, and therefore applied the name Negros to the large island in the Visayas where they still dominated (Rahman & Maceda 1955).[5] Loarca reported in 1582 that Negros had a population of only 6,000-7,000 Indios, but this excluded the Negritos whose numbers 'could not be ascertained because of their hostility' (cited by Newson 2009: 74). Negros is also home to the Central Philippines' most active volcano, Kanlaon (26 eruptions of VEI 1 or 2 since 1919). Nothing is yet known about the history of this volcano before Negros was taken over by sugar cultivation in the nineteenth century, but the minimal place of agriculture on its rich soils in earlier times suggests an eruption strong enough to have destroyed or

5 The sugar industry quickly transformed the formerly forested Negros after 1860. In 1889 Blumentritt cited a Spanish source that the Negritos were still numerous in the forests around the mountain, but 'weak and sickly, and decreasing in number'. Diaz Arenas had estimated their population at 3,475 in 1850, before the sugar invasion, but this number declined quickly thereafter to be only a handful, having lost their languages, by the 1950s. Deforestation in the twentieth century removed their remaining habitat..

deterred earlier agriculturalists. After sugar in Negros destroyed their habitat, the strongest Negrito survivals were the Aetas, on slopes exposed to Mount Pinatubo's mega-eruptions, the last of which before 1991 were around 1450CE and 1000 BCE (Smithsonian GVP).The Aetas demonstrated their exemplary flexibility and mobility in locating food sources at the time of the 1991 eruption. After typhoons also, it had been noted, poor agriculturalists sought to marry into Aeta families for survival (Seitz 1998). It seems likely, therefore, that just as rapid expansion of agriculture and population has threatened the survival of hunter-gatherers in the last two hundred years, similar expansions threatened them in the past only to be checked by natural disaster.

FUTURE RESEARCH

More extensive cross-disciplinary research into the volcanic record is needed to help us appreciate not only likely future dangers to population, but also the very uneven and interrupted character of Indonesian population expansion in the past.

CONCLUSION

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