Time-varying interseismic strain rates and similar seismic ruptures on the Nias–Simeulue patch of the Sunda megathrust

Aron J. Meltzner, Kerry Sieh, Hong-Wei Chiang, Chung-Che Wu, Louisa L. H. Tsang, Chuan-Chou Shen, Emma M. Hill, Bambang W. Suwargadi, Danny H. Natawidjaja, Belle Philibosian, and Richard W. Briggs

Supplementary Material

Introduction

This Supplementary Material contains photos of selected coral microatolls used in this study (Figure S1); a general discussion of diedowns and dating (Text S1); detailed discussions of our study sites and corals (Text S2–S13 and Figures S1–S86); and details of our modeling of interseismic rates (Text S14 and Figures S87–S88). In sequence, we describe observations from sites on southern Simeulue (sites SLR, SMB, UTG, LBJ, and LAT), Bangkaru (site PBK), and Nias (sites PWG, AFL, PSN, MZL, BWL, and LAG). Time series of relative sea level (RSL) appear individually for most sites as part of the site's detailed discussion, and also as composite figures for Simeulue, Bangkaru, and Nias for the 18th–19th centuries (Figures S81–S83, respectively) and for the 20th century (Figures S84–S86, respectively). Supplementary tables provide details on all the corals sampled from southern Simeulue, Bangkaru, and Nias (Table S1); complete results of U-Th dating analyses on all fossil coral samples (Table S2); dates of death of each coral, determined by calculating weighted averages of all dates from that coral (Table S3); and information related to our modeling efforts (Table S4). An appendix (Appendix S1) provides selected primary historical accounts from the 1843, 1861, and 1907 earthquakes.

Text S1. Diedowns and Dating of Corals

1.1. Coral Diedowns

Microatolls form when coral colonies living at the very base of the intertidal zone grow high enough, or RSL falls low enough, that the uppermost part of a coral colony gets sufficiently exposed so that those polyps desiccate and die. As in previous papers [Meltzner et al., 2010, 2012; Meltzner and Woodroffe, 2015], we use the term "diedown" to refer to a partial mortality event on a coral colony in which the portion of a coral above a certain elevation—the highest level of survival, or HLS [Taylor et al., 1987]—dies, while coral polyps at lower elevations live and continue to grow radially outward and upward.

Unlike a complete mortality of a coral colony, for which the interpretation of the cause of death is not always straightforward, a diedown to a uniform elevation around the entire perimeter of the coral indicates a drop in RSL. This drop in RSL might be very short-lived, such as during an extreme low tide or during a strong positive Indian Ocean Dipole (IOD) event, in which RSL along the entire west coast of Sumatra lowers by decimeters for several weeks to months. Alternatively, the drop in RSL might be very long-lasting, such as occurs in the case of tectonic uplift. Nonetheless, a diedown and the subsequent growth back up (until the next diedown) forms a concentric ring on the upper surface of the microatoll and preserves a record of RSL at the time. Commonly, diedowns that result from tectonic uplift affect corals at sites ten to a few hundred kilometers apart, depending upon the dimensions of the associated rupture. Larger-amplitude diedowns (~5 cm or more) that result from oceanographic phenomena tend to be ubiquitous over spatial scales of hundreds of kilometers.

When we extract a slab cross-section from a coral microatoll, the concentric rings manifest as ridges on the slab's upper surface. On corals that are better preserved, the diedown "unconformity" can still be seen in the slab, and the tops of subsequent annual growth bands distinctively curl over, as polyps just below the HLS try to grow upward. On eroded slabs, however, the unconformity and the upper parts of preceding bands may have been destroyed, and the ridge on the slab's upper surface may be the only remaining evidence of a diedown. In cases of severe erosion, all evidence for the diedown may have been erased from the slab, but if we had observed a concentric ring along other sectors of the microatoll's surface, we can project that ring into the plane of the slab and estimate the location (timing) of a diedown in that manner.

On the annotated coral slab cross-sections presented in this Supplementary Material, we delineate diedown unconformities, where they were preserved in the slab, with thick black lines. For convenience, we extend those unconformities downward with thick cyan dotted lines;

because the cyan dotted lines are parallel to banding, they represent the outer living surface of the coral, below HLS, at the time of the diedown. Elsewhere, where an unconformity is not preserved but we nonetheless identified a concentric ring on the coral's upper surface, we estimate the location of the diedown in the plane of the slab with a thick magenta dotted line. In cases where the unconformity is preserved, the timing of the diedown is fairly tightly determined; however, even in the best cases, there is an implicit uncertainty in the timing of diedowns of about ± 2–4 months, due to small-scale irregularities in the banding (perhaps a result of seasonal differences from one year to the next) and due to variability in the coral growth rate at different times of the year. For diedowns inferred from the coral morphology, however, there is commonly ± 2–3 years' uncertainty in the timing, or worse.

1.2. Determining the Timing of Diedowns and the Age of a Coral

We consider three pieces of information when determining the age of a coral and the timing of individual diedowns on those corals. Although we might rely solely on the U-Th dates—and in many cases they are remarkably precise—we can improve upon the dating precision by also considering historical information (for this study, we know the dates of the larger earthquakes), and by closely examining the diedowns themselves.

To start, we date one or more samples extracted from the slab using U-Th techniques [Shen et al., 2002, 2008, 2010; Frohlich et al., 2009]. We then combine all the dates from an individual coral slab, using weighted averages and the known age gap (number of annual bands) between the various samples, as discussed by Meltzner and Woodroffe [2015] and shown in Table S3.

A second consideration in the age determination is the coral's diedown history. As alluded to earlier, the strongest positive IOD events should have resulted in substantial diedowns (several centimeters or more) that occurred synchronously on all microatolls at all sites on Simeulue, Bangkaru, and Nias; moderate positive IOD events may have affected most microatolls but perhaps not those with slower upward growth rates. Indeed, examining the modern microatolls (those that died from uplift in 2005), diedowns occurred in late 1997 (or early 1998) and in late 1961 (or early 1962) at every site where we recovered a coral record from the time; additionally, except for slab BWL-1, whose pre-1991 record is irregular, every microatoll recorded a diedown in late 1982 (or early 1983). All three of those dates correspond to widely documented severe positive IOD events [Rao et al, 2002; Meltzner et al., 2010]. Additional widespread diedowns affected most of our corals around late 1986, late 1991, and late 1994.

Similarly, the 19th-century fossil microatolls tend to have prominent diedowns mid-way through an annual band ~44 years before their ultimate death (we will call this band "1817"), at the very beginning of another annual band 15.5 years later ("1833"), and, though less ubiquitous, mid-way through a third band 13.5 years thereafter ("1846"). When the U-Th dates from a particular slab indicate it is reasonable to do so, we commonly use the 15.5-year and/or 13.5-year diedown intervals, coupled with the observation that the "1817" and "1833" diedowns tend to be among the largest on each slab, to correlate individual annual bands between corals and to improve the dating precision in general.

The third consideration in determining a coral's age is historical information. In cases where U-Th analyses suggest a coral's outer preserved band slightly post-dates AD 1861, but the 2σ error allows for the possibility that it instead barely pre-dates 1861, we strongly considered the latter interpretation, particularly where nearby corals independently suggest that the 1861 uplift was substantial. In a few other cases, U-Th analyses suggest corals survived the 1861 uplift and continued growing for several decades; if those corals recorded a prominent diedown around the year 1861, we inferred the exact timing of that diedown to be early 1861 and estimated the age of the rest of the slab accordingly.

Lastly, two corals from the AFL site on Nias have dates for their respective outer bands that are consistent with death in 1843 but not in 1861. AFL-3 was a *Porites* microatoll that we found mostly buried in an organic-rich sand layer that had likely protected it from erosion since soon after its death; its outer surface was nearly pristine (suggesting erosion of no more than a few millimeters or a fraction of one annual band), and its outer band dated to AD 1836 ± 21. Nearby, a *Goniastrea* coral, AFL-4, also had a notably pristine outer surface, and we inferred in the field that it was killed by the same uplift as AFL-3; its outer band dated to AD 1843 ± 2. Because historical records tell of a large earthquake and tsunami on Nias in 1843, we have reasonable confidence in attributing the uplift that killed these two corals to 1843.

We now return to the discussion of the "1833" and other 19th-century diedowns. The timing of a diedown around 1833 is of particular interest because of a large megathrust rupture on the Mentawai patch of the Sunda megathrust, south of the 2005 rupture, in November 1833. A curious observation by Natawidjaja et al. [2006] was that, in spite of the suggestion by most other evidence that the 1833 rupture extended northward only to Sipora island at latitude 2° S, one microatoll at Badgugu in the Batu Islands, at latitude 0.5° S, recorded a diedown sometime in 1833 of 12 ± 5 cm. Based on information available at the time, Natawidjaja et al. [2006] interpreted the 1833 Badgugu diedown as uplift, although they noted it was unclear whether it was connected to or isolated from the main region of uplift in 1833.

Two corals from the Nias–Simeulue patch allow us to precisely estimate the timing of the "1833" diedown on Simeulue, Bangkaru, and Nias, and, presumably, at Badgugu. First, we consider AFL-3, from northwestern Nias. In addition to the exceptional preservation of this coral, it also has especially clear annual banding, leaving no ambiguities in band counting. Assuming that AFL-3 died in the January 1843 earthquake and that subsequent erosion removed no more than a fraction of an annual band, we count back to a prominent diedown that occurred at the beginning of the 1833 band, i.e., in early 1833 or very late 1832 (Figure S55). Although highly unlikely, if more erosion of AFL-3 occurred than we recognized, and if one or more bands are completely missing, this would push the "1833" diedown earlier, but not later.

At the LAG site on southwestern Nias, an irregular coral, LAG-3B, accurately records the timing between the "1833" diedown and the 1861 earthquake. LAG-3B appears to have survived the 1861 uplift by tilting and settling during shaking in 1861: it recorded a diedown in 1861, but by lowering its elevation relative to the substrate at the moment of the uplift, its lower half survived when every other coral we slabbed at this site died entirely. Although the post-"1833" HLS is no longer at its original elevation because of the tilting and settling, the preservation of the diedown unconformities from both "1833" and the 1861 uplift allow us to precisely count the number of annual growth bands between the two diedowns to accurately date the earlier diedown. Our best estimate from LAG-3B is that the diedown occurred at the end of the 1832 band, i.e., in late 1832 or very early 1833 (Figure S78).

The two estimates of the timing of the "1833" diedown agree within the implicit uncertainty associated with each estimate, about ± 2–4 months, and collectively they suggest the diedown occurred between October 1832 and March 1833. This would date the diedown to roughly a full year before the November 1833 earthquake. Given that the late 1832 / early 1833 diedown occurs at every site from central Simeulue (2.7° N) to southern Nias (0.6° N), and given that it exceeds 8 cm at multiple sites (and it exceeds 11 cm at the MZL site on northern Nias), we would expect to see a similar diedown in late 1832 or early 1833 at Badgugu (0.5° S), purely related to oceanographic phenomena such as the IOD, and not a result of tectonic uplift.

Counting bands inward and outward from 1833, we estimate that the "1817" and "1846" diedowns occurred in the middle of the years 1817 and 1846, respectively.

1.3. A Note on the Reported U-Th Lab Errors

Looking at the U-Th dating results for all the fossil slabs carefully analyzed in this paper, in 26 of 34 cases, our preferred dates (in blue on the annotated slabs) lie within the 2σ errors of the weighted average U-Th dates (in black). Although the different types of dates are not independent—i.e., our preferred dates were chosen in consideration of the U-Th dates—the 8 cases in which the dates do not agree are cases where we have carefully considered the U-Th dating results yet determined that they cannot reasonably be correct. If the lab-reported 2σ errors accurately reflect the true uncertainty of those U-Th dates, we would expect the true age to exceed the errors about 5% of the time, or in only 1 or 2 of the 34 cases. This suggests the reported lab errors underestimate the true uncertainty of the dates. If we arbitrarily multiply each lab error by 170%, then only 4 of 34 U-Th dates are exceeded; if we arbitrarily multiply each lab error by 175%, then the number of exceeded U-Th dates drops to 2 of 34. This hints at the likelihood that either our logic for determining the true age of the corals is faulty, or that the reported U-Th lab errors must be multiplied by ≥175% to reflect the true uncertainty of the dates.

Text S2. Results from the Silinggar (SLR) Site

The Silinggar site sits at the end of a peninsula jutting out into the Indian Ocean along the central northeast coast of Simeulue, between Teluk Dalam ("Deep Bay") to the south and a smaller embayment to the north, near Silinggar (or Silingar) village (Figure S2). The site was uplifted ~52 cm during the 2005 earthquake but experienced little vertical change in 2004. (Uplifts in 2004 and 2005 reported herein are determined following Meltzner et al. [2010, 2012].) In addition, Silinggar rose ~5 cm during the M_W 7.2 earthquake of 2 November 2002, which had a locus of deformation centered ~15 km to the southwest, directly trenchward, and it rose a similar amount during the M_W 7.3 earthquake of 20 February 2008, centered ~25 km to the west [Meltzner et al., 2012]. We sampled one modern and one fossil microatoll at Silinggar.

2.1. Modern Paleogeodetic Record at SLR

The modern microatoll from the SLR site, SLR-1, records interseismic subsidence from 1961 to 2002, followed by minor uplift associated with the 2002 earthquake and complete death due to uplift in 2005 (Figures S3 and S6). SLR-1 recorded diedowns in late 1961, late 1982, late 1991, late 1997, late 2003, and late 2004, before its ultimate death in 2005. Diedowns on each of these dates are seen at most or all sites across northern and central Simeulue [Meltzner et al., 2010, 2012]. We infer the 1961, 1982, 1991, and 1997 diedowns to have resulted from broad transient oceanographic lowerings. In particular, the three largest of these—in 1961, 1982, and 1997—coincided with strong positive Indian Ocean Dipole (IOD) events [Rao et al., 2002], which correlate with lower sea surface heights off the west coast of Sumatra [Taylor et al., 1987; Woodroffe and McLean, 1990; Brown et al., 2002; van Woesik, 2004; Meltzner et al., 2010].

We attribute the small diedowns in late 2003 (or early 2004) and late 2004 (or very early 2005) to minor uplift in 2002 that did not impact the coral until brief periods of low sea-level anomalies in early 2004 and even lower sea-level anomalies in early 2005 [Meltzner et al., 2010].

The central part of the coral, prior to ~1960, is nearly upside-down, suggesting it was overturned sometime around 1961. Although the late 1961 diedown may be related to that overturning, we note that the 1961 diedown occurred on what is presently the highest part of the 1961 band, suggesting the coral was already in its present orientation by the time of the diedown. The cause of the overturning of the coral is unknown but it appears to be an isolated incident; perhaps the coral was small enough that a storm moved it, sometime during or prior to 1961.

2.2. Fossil Paleogeodetic Record at SLR

The fossil microatoll from the SLR site, SLR-2, records a history of RSL for ~60 years prior to the 1861 earthquake (Figures S4 and S5). Based on banding analysis of the slab and the morphology of the coral's upper surface, we inferred diedowns around early 1800, mid-1817, early 1833, and early 1849; of those, only the 1849 unconformity is directly preserved in the slab.

The U-Th dates provide a compelling case that this coral died in 1861: the weighted average U-Th date for the outer preserved band is AD 1860.7 ± 1.9 (Table S3). That date's remarkable proximity to 1861 notwithstanding, we estimate that the outer preserved band actually grew in 1858, based on correlations of the 1817 and 1833 diedowns to diedowns at other sites (Figure S4). Also based on these correlations, we infer that two full annual bands, and a fraction of a third, have been entirely eroded (Table S3), an inference supported by the modest erosion of SLR-2 that was apparent in the field. We make a minimum estimate of 1861 uplift based on the elevation difference between the top and bottom of the outer preserved band, which is 45 cm.

The coral's morphology (Figure S4) and time series (Figure S5) suggest an initial period of slow interseismic submergence, followed by a brief period of more rapid submergence. Although a quick assessment of the time series may suggest that the change to a faster subsidence rate may have occurred around 1833, this was biased by the fact that the 1833 oceanographic lowering caused a severe diedown, after which the coral needed 16 years to grow back up to HLS; any rate calculated strictly for the period between 1833 and 1849 would reflect the vertical growth rate of the coral rather than a rate of submergence. Indeed, if the pre-1833 submergence rate is extrapolated to 1849, we see that SLR-2 had just grown back up to its pre-1833 position, before experiencing the small diedown in 1849. The time series can be fit by a linear submergence rate of 0.9 mm/yr prior to 1849 and a rate of 4.8 mm/yr thereafter.

Text S3. Results from the Sambay (SMB) Site

The Sambay site lies 8 km southeast of the Silinggar site, near Sambay (or Sambai) village. It sits on the eastern (seaward) side of the large peninsula that bounds Teluk Dalam to the east (Figure S7). The site was uplifted ~6 cm in 2002, ~5 cm in 2004, and ~78 cm in 2005, with little vertical change in 2008. The 2004 uplift here (and at the UTG site to the southeast) may have been isolated from the main region of 2004 uplift to the northwest. We sampled one modern and two fossil microatolls at Sambay.

3.1. Modern Paleogeodetic Record at SMB

The modern microatoll from the SMB site, SMB-1, contains only a brief record. It records interseismic subsidence from 1986 to 2002, followed by minor uplifts associated with the 2002 and 2004 earthquakes, before its death due to uplift in 2005 (Figures S8 and S12). The diedowns recorded by SMB-1 in late 1986 and late 1997 are seen at most or all sites across northern and central Simeulue [Meltzner et al., 2010, 2012]. As at SLR, we attribute the late 2003 (or early 2004) diedown to minor uplift in 2002 that did not impact the coral until a period of particularly low sea-level anomalies in early 2004. The late 2004 diedown is large enough at the SMB site that it must have resulted from uplift at around the time of the 2004 earthquake.

3.2. Fossil Paleogeodetic Record at SMB

Two fossil microatolls combine to provide a century-long record of RSL at the SMB site, from 1760 until the 1861 uplift. SMB-3 (Figure S10) was one of a cluster of microatolls that were isolated initially but gradually grew towards one another. Although we did not recognize it when we slabbed the corals, subsequent analysis of growth bands, consideration of U-Th dates, and a return to the site in 2009 for further documentation revealed that this coral died because it grew into an adjacent coeval coral and ran out of space within which to grow. SMB-3 died ~20 years before the 1861 uplift, but it records a history of RSL for eight decades prior to its death. Thirty meters away, SMB-2 (Figure S9) was a lone tilted quadrant of a microatoll that may have been transported at some point after its death by a tsunami. Because only a sector of the microatoll remained, we could not determine its original horizontality (or elevation) simply by surveying it in the field; nonetheless, its six-decade record of RSL overlaps by 40 years with that of SMB-3, so the original untilted horizontality and elevation of SMB-2 can be restored by comparing the elevations of the three diedowns in common between the two slabs.

The U-Th dates and diedown correlations suggest diedowns in early 1760, early 1800, mid-1817, mid-1819 (a very minor diedown affecting only SMB-2), early 1833, and mid-1846; notably, several of these are also seen at SLR. Once the original horizontality and elevation of SMB-2 are restored, the agreement between the two corals is quite good (Figure S11); there is little uncertainty in how much rotation should be applied to correct for the tilting of SMB-2. Combined, the records suggest an initial period of slow interseismic submergence (0.8 mm/yr from 1760 until ~1819), followed by much more rapid submergence (8.7 mm/yr) until the 1861 uplift. The dramatic increase in submergence is striking and begs the question of whether the rate could be biased high because we needed to "untilt" the SMB-2 slab. A comparison of the records from SMB-2 and SMB-3, however, reveals that the rate change is already captured by SMB-3, and SMB-2 merely extends the faster post-1819 rate an additional 20 years until the 1861 uplift. Although the SMB-2 and SMB-3 records may appear to disagree prior to ~1793, the lower elevations recorded by SMB-2 prior to 1800 are merely minimum estimates of RSL, and therefore are not inconsistent with the higher elevations recorded for that period by SMB-3.

Text S4. Results from the Ujung Tinggi (UTG) Site

The Ujung Tinggi site also lies along the northeast coast of Simeulue, 12 km southeast of Sambay, near Ujung Tinggi village (Figure S13). The site was uplifted ~7 cm in 2002, ~3 cm in 2004, and ~100 cm in 2005, and it subsided ~13 cm in 2008. As at Sambay, the 2004 uplift here may have been isolated from the main region of 2004 uplift to the northwest. We sampled one modern and eight fossil microatolls at Ujung Tinggi.

4.1. Modern Paleogeodetic Record at UTG

The modern microatoll from the UTG site, UTG-1, records interseismic subsidence from 1982 to 2002, followed by minor uplifts associated with the 2002 and 2004 earthquakes, before its death due to uplift in 2005 (Figures S14 and S22). As at other sites, we attribute the diedowns recorded by UTG-1 in late 1982, late 1986, late 1991, and late 1997 to geographically broad oceanographic lowerings, and we attribute the late 2003 (or early 2004) and late 2004 diedowns to minor uplift in 2002 and 2004, respectively.

4.2. Fossil Paleogeodetic Record at UTG

The crux of the fossil record at UTG comes from two *Porites* microatolls, UTG-4 and UTG-5, at the eastern end of the site (Figures S15 and S16, respectively). Together, they provide a record of RSL at the UTG site from ~1757 until the 1861 uplift. Although irregularities on these two corals' upper surfaces led in the field to uncertainty as to whether they were coeval, the U-Th dates and diedown analyses reveal that they did overlap in time. Indeed, these corals provide a redundant and consistent history of RSL for the century preceding the 1861 uplift (Figure S21). It turns out to be fortunate that we slabbed both microatolls, because while UTG-4 extends back farther in time, the most recent unconformities are preserved only on UTG-5. Although the high-precision U-Th dates on both UTG-4 and UTG-5 suggest these microatolls are 6–10 years older, the diedown correlations, combined with a consideration that UTG-4 has sustained moderate erosion and is likely missing several outer growth bands entirely, suggest that these corals died in 1861 and not, as might be proposed based on the U-Th dates alone, in 1843.

UTG-6 and UTG-8 (Figures S17 and S19, respectively) were *Goniastrea* microatolls at the western end of the site that provide compelling evidence for uplift in 1861, but not in 1843, and support the interpretation that UTG-4, UTG-5, and other corals at the site were killed in 1861. *Goniastrea* microatolls, which tend to yield more precise U-Th dates and are more erosion resistant, are particularly useful for dating past events, but they commonly grow ~10 cm higher than neighboring *Porites* counterparts [Natawidjaja et al., 2006], and frequent changes in their growth direction typically make it difficult to trace banding in a single cross section for more than a few decades. Along with UTG-7 (Figure S18), an adjacent *Porites* microatoll, UTG-6 and UTG-8 were buried under a beach berm soon after their deaths, but at some point, likely recently, they were re-exposed when the berm was eroded locally by a spring. Because they had spent substantial time since their death protected under the berm, UTG-6, UTG-7, and UTG-8 were especially well preserved. UTG-6 and UTG-8 provide very precise estimates of the timing of their deaths, which agree with the 1861 earthquake. UTG-7 also yielded a U-Th date that overlaps with 1861; given its good preservation, we assign banding ages to UTG-7 such that its outer unconformity corresponds to the outer unconformity on UTG-6 and UTG-8 (mid-1855), and such that UTG-7 is missing only two bands. UTG-6 and UTG-8 were 10–13 cm higher than UTG-7 (Table S3), consistent with the difference between coeval *Goniastrea* and *Porites* microatolls. UTG-7 was 6–7 cm higher than UTG-4 and UTG-5, but that can be explained by the greater amount of erosion of UTG-4 and UTG-5, and by the fact that both UTG-4 and UTG-5 were slightly tilted and may have settled by a few centimeters. (We can correct for tilting, but settling is not always obvious.)

Another *Goniastrea* microatoll, UTG-3, was found next to UTG-6, UTG-7, and UTG-8, but it was slightly lower (Table S3), and the errors on the U-Th date for UTG-3 were so large that UTG-3 does not provide useful information. It will not be discussed further in this paper.

Two other *Goniastrea* microatolls were slabbed at the site. The U-Th date on UTG-9 (Figure S20) suggests it died around AD 1820, although other microatolls at the site preclude an uplift at that time. A large diedown several years before the ultimate death of UTG-9 likely corresponds to the mid-1817 diedown, but it is unclear why UTG-9 eventually died. Corals sometimes die for reasons other than uplift, which is why any tectonic interpretation relies upon (*a*) partial diedowns to a uniform post-diedown HLS, (*b*) consistent simultaneous coral mortality at multiple sites, or (*c*) supporting historical information. The U-Th date on UTG-2 suggests it died around AD 1780, although other microatolls at the site preclude an uplift at that time. We will defer discussion and interpretation of UTG-2 and other older corals to a later paper.

The UTG-4 and UTG-5 corals suggest diedowns in early 1757, early 1772, mid-1799 (given the imprecision of the timing of the inferred diedown, it could be early 1800), mid-1817, early 1833, and mid-1846; those from ~1800 onward are also seen at SMB. The especially well preserved microatolls UTG-6, UTG-7, and UTG-8 suggest additional minor diedowns in early 1850 and mid-1855. UTG-9 suggests a further minor diedown in early 1806. Questions arise as to whether the "1757" diedown on UTG-4 coincides with the "1760" diedown on SMB-3, and whether the number of bands following that diedown might have been miscounted on one or both corals; while we believe our counting is correct, there is a region of indistinct banding on SMB-3, ~15 years after the "1760" diedown, that we may have miscounted. Unfortunately, we cannot answer these questions definitively with data presently available. The UTG-4 and UTG-5 records suggest an initial period of slow submergence (1.1 mm/yr from 1757 until ~1839), followed by much more rapid submergence (7.0 mm/yr) until the 1861 uplift (Figure S21).

Text S5. Results from the Labuhan Bajau (LBJ) Site

The Labuhan Bajau site lies 30 km southeast of Ujung Tinggi, along the east coast of Simeulue, near the southeastern end of the island and Labuhan Bajau (or Labuan Bajau) village (Figure S23). The site was uplifted ~88 cm in 2005, with apparently little vertical change in 2002, 2004, or 2008. The site actually consists of two subsites: LBJ-A, on "mainland" Simeulue, and LBJ-B, 1.8 km to the north-northeast, on Pulau Batu Belahir, a smaller island off the east coast of Simeulue. (Pulau Batu Belahir is separated from Simeulue by a channel that is only 150 m wide.) We sampled one modern and two fossil microatolls at LBJ-A, and two additional fossil microatolls at LBJ-B. One fossil microatoll at LBJ-A, and both at LBJ-B, dated to the early 16th century (Table S3), so we will not discuss them further in this paper. In this paper, we will discuss only subsite LBJ-A, which, henceforth, we will refer to simply as site LBJ.

5.1. Modern Paleogeodetic Record at LBJ

The modern microatoll from the LBJ site, LBJ-1, contains the longest RSL record of any modern microatoll we recovered from the Nias–Southern Simeulue patch (Figures S24 and S27). It records diedowns in late 1945, late 1948, late 1956, late 1961, late 1973, late 1982, late 1991, late 1994, and late 1997. Except for the 1973 diedown, all of these are seen at sites on northern or central Simeulue, as well [Meltzner et al., 2010, 2012]. (The late 1948 diedown is described as an "early 1949" diedown at site LKP on northern Simeulue, and the late 1994 diedown shows up on a microatoll at site ULB.) LBJ-1 records rapid interseismic submergence of 10.2 mm/yr from 1945 to 1997, which, adjusting for 20th-century sea-level rise, indicates about 8.2 mm/yr of tectonic subsidence.

5.2. Fossil Paleogeodetic Record at LBJ (18th–19th Centuries)

Fossil microatoll LBJ-2 was a very tall, very wide microatoll, with a nearly flat central top surrounded by three concentric "stair steps" rising toward the microatoll's perimeter. Indeed, numerous fossil microatolls had this characteristic morphology, at both the LBJ site, and 1.8 km to the north-northeast at LBJ-B (Figures S1 and S25). Paralleling the modern microatoll from this site, LBJ-2 provides the longest RSL record of any fossil microatoll we recovered from the Nias–Southern Simeulue patch (Figure S26), with a continuous record from 1738 until 1861. The annual growth bands are consistently clear in the x-ray and are of uniform thickness throughout the microatoll, making this slab ideal for band counting. Unfortunately, none of the unconformities are preserved in the slab, but the concentric rings on the coral's upper surface are distinct enough that this is not a big problem. We interpret diedowns around early 1738, early 1759, early 1790, mid-1817, early 1833, mid-1846, and mid-1854. The ~1759 diedown, whose location we assign an uncertainty of ±2 annual growth bands, may correlate with the "1757" diedown on UTG-4 and/or the "1760" diedown on SMB-3. The LBJ-2 record suggests an initial period of slow interseismic submergence (1.6 mm/yr from 1738 until ~1838), followed by more rapid submergence (6.1 mm/yr) until the 1861 uplift. Based on the height of what was the outer living perimeter of LBJ-2 just prior to its death, and assuming the entire microatoll died because of uplift, we estimate the minimum 1861 uplift at site LBJ to be 110 cm.

Text S6. Results from the Latiung (LAT) Site

The Latiung site lies in a small embayment 7 km south-southwest of Labuhan Bajau, near the southeastern tip of Simeulue, and near Latiung village. We did not visit this site until 2012, and then only with a hammer and chisel, as we made one final attempt to find a site trenchward of SLR, SMB, UTG, and LBJ that had microatolls living at the start of 1861 to record RSL changes associated with the earthquake.

6.1. Fossil Paleogeodetic Record at LAT

At the Latiung site, we found a population of tall, very wide microatolls, each with a nearly flat center surrounded by three concentric "stair steps" rising toward the microatoll's perimeter (Figure S1). Their striking resemblance to LBJ-2, 7 km away, strongly suggested that they recorded a similar RSL history over the identical period of time. We chiseled and dated samples from two microatolls in this population, LAT-1 and LAT-2, and confirmed that they both died around 1861 (Table S3). A third microatoll, LAT-3, found nearby, had a different morphology and was inferred to be older; indeed, the U-Th date from LAT-3 suggests it was coeval with one or more of the older microatolls from LBJ and LBJ-B, dating to the early 16th century (Table S3).

A fourth microatoll, LAT-4, grew 250 m to the southeast, on the opposite side of the embayment. It was by far the largest microatoll at the site, with a diameter of 4.3 m. Its irregular morphology led us to believe that it, too, was a separate generation, but the dating result suggests that it died either in 1861 or during the preceding ~60 years. Unfortunately, the coral's irregular morphology, the lack of a slab, our imprecise elevation control at the site, and the large error on the U-Th date all make interpretation of this microatoll difficult, but if it died (for whatever reason) several decades before the 1861 earthquake (perhaps its outer rings do not correlate with those on LAT-1, LAT-2, and LBJ-2), then its RSL record may extend back to the beginning of the 18th century.

Text S7. Results from the Pulau Bangkaru (PBK) Site

The Pulau Bangkaru ("Bangkaru Island") site lies along the northeast coast of Bangkaru, near the island's northern tip (Figure S28). The site was uplifted ~34 cm in 2005, with an additional ~17 cm of postseismic uplift between our initial measurement in May 2005 and subsequent measurements in January 2009. The site then experienced ~16 cm of subsidence between January 2009 and July 2010, which is inferred to be largely or entirely coseismic deformation during the M_W 7.8 earthquake of 6 April 2010. The site consists of three subsites: PBK-A to the northwest; PBK-B, 0.4–0.9 km southeast of PBK-A; and PBK-C, 1.5 km southeast of PBK-A. We sampled a total of two modern and ten fossil microatolls at the PBK subsites.

7.1. Vertical Deformation at PBK from Repeat Surveying, 2005–2010

Following the March 2005 earthquake, we visited the PBK sites in May 2005, July 2007, January 2009, and, following the April 2010 earthquake, in July 2010. During each visit, we surveyed the elevation of the pre-2005 highest level of growth (HLG) on numerous *Porites* microatolls with respect to water level at the time of the survey; we then adjusted the water levels to a common datum by correcting for the tide and sea level anomaly at the time of each survey, following methods described by Meltzner et al. [2010]. From these surveys, we estimate the net uplift as of the times of our visits in 2005, 2007, 2009, and 2010 to be ~34 cm, ~44 cm, ~51 cm, and ~35 cm, respectively. We interpret the initial ~34 cm measurement to represent coseismic uplift in 2005 plus the first two months of postseismic uplift, with ~10 cm of additional postseismic uplift between May 2005 and July 2007, and another ~7 cm of postseismic uplift between July 2007 and January 2009. We interpret the difference between the January 2009 and July 2010 measurements to be dominated by ~16 cm of coseismic subsidence locally in the April 2010 earthquake.

7.2. Modern Paleogeodetic Record at PBK

In our initial reconnaissance of the PBK subsites, we observed that the modern microatolls there tended to have more closely spaced diedowns than we were accustomed to at other sites. Based on subsequent analysis of the slabbed modern microatoll, PBK-4, we now understand this to be a consequence of an exceptionally rapid coral growth rate, coupled with a fairly slow rate of interseismic subsidence (or even, at times, uplift). In principle, one or more years after the most recent diedown, a microatoll with a faster growth rate, or at a site with a slower subsidence rate, will have an HLG that is slightly higher than otherwise; all else being equal, the frequency of diedowns on such a microatoll should be greater.

Indeed, the PBK-4 slab reveals a consistent growth rate of 25 mm/yr (Figure S34), far faster than the typical 11–17 mm/yr growth rate for *Porites* microatolls from Simeulue and Nias, and faster than the previous "records" of 21 mm/yr in slab LWK-1, from the northern tip of Simeulue [Meltzner et al., 2010], and 20–22 mm/yr in slab AFL-1, on Nias (to be discussed in Text S9). From its initial diedown in late 1956, PBK-4 recorded a total of 27 distinct diedowns prior to its death by uplift, 49 years later, in 2005 (Figure S34). By comparison, LWK-1 experienced 12 diedowns over the same period; AFL-1, where the interseismic subsidence was faster, experienced 10 diedowns; and other corals generally experienced 10 diedowns or less.

PBK-4 was a very thin, pancake-shaped microatoll. Although it had little relief and grew barely higher than the underlying substrate, we were at the site as the tide went out, and no ponding of water occurred. (In general, ponded or "moated" microatolls are not observed on the reefs of the Sumatran outer-arc islands, perhaps because those reefs are sufficiently narrow to avoid this complication.) For the sake of redundancy, we x-rayed and analyzed three parallel slices from the radial PBK-4 slab, as many diedowns were small and easily could have been missing or eroded from one or more of the slices (Figure S34).

PBK-4 starts with standard upward growth, but after several successively higher diedowns, there is an abrupt change in this trend, and for ~15 years, successive diedowns are lower and lower; the trend then, just as suddenly, reverses again, and successive diedowns are higher (Figure S46). Applying a linear regression, the rates of RSL change we estimate from PBK-4 are: ~4.7 mm/yr RSL rise from 1956 to 1966, ~5.8 mm/yr RSL fall from 1966 to 1981, and ~4.4 mm/yr RSL rise from 1981 until 2005. Adjusting for 20th-century sea-level rise at a rate of 2 mm/yr, these rates indicate that the site experienced ~2.7 mm/yr of tectonic subsidence from 1956 to 1966, followed by ~7.8 mm/yr of tectonic uplift from 1966 to 1981, before reverting to ~2.4 mm/yr of tectonic subsidence from 1981 until 2005 (Figure 15; Table 2).

Because each of these three time periods spans so many diedowns, the method proposed by Meltzner et al. [2012] for estimating errors on the rates of interseismic deformation is overly conservative for the PBK-4 slab: Meltzner et al. [2012] considered a "worst-case scenario" in which there is "an 8-cm error in the apparent elevation gain recorded by a microatoll slab due to differential erosion of one part of the head compared to another part, or due to deficient upward growth." In the case of PBK-4, the microatoll's frequent diedowns and excellent preservation preclude such errors, and the largest remaining source of error in determining the rates is simply the scatter of the data about a line. Hence, for the errors in the rates determined from PBK-4, we simply adopt the respective standard errors from the linear least squares analyses. The rates of RSL change and tectonic deformation, all with appropriate errors, are listed in Table 2.

In addition to modern microatoll PBK-4, which we slabbed in 2009, we had, in 2007, chiseled a sample out of the outer ring of another modern microatoll, PBK-1. Prior to 2005, PBK-1 had been one of many living microatolls at the site, unremarkable in any way. During the shaking in the 2005 earthquake, however, it tilted severely, and after tilting the lowest side of the microatoll was low enough that it was below HLS and remained alive, even after the 2005 uplift. As is suggested by the banding in the x-ray of PBK-1 (Figure S29), the diedown following the moment of shaking, tilting, and uplift in 2005 was not instantaneous, but instead was gradual, or at least episodic: there is a vertical span of 4–12 cm of the coral that had survived to late 2005, but had died before we collected the sample in July 2007. This interpretation of a gradual or episodic diedown on PBK-1 suggests the fall in RSL was gradual, and that is supported by our repeated surveys of the site, discussed earlier in Text S7.1.

7.3. Fossil Paleogeodetic Record at PBK

Fossil microatolls PBK-5, PBK-6, PBK-7, and PBK-8 were sampled from a population of microatolls at the PBK-B subsite. The close proximity of these microatolls, and similarities in their morphologies and elevations, suggested they were all from the same generation, but we slabbed all four because we believed each would contribute unique information to the record. PBK-5 (Figure S35) was the biggest, and we anticipated its record would go back in time the farthest. PBK-6 (Figure S36) was a *Goniastrea* microatoll that we anticipated would yield a precise U-Th age estimate. The central hemisphere of PBK-7 (Figure S37) appeared to correlate with the outer rim of PBK-5, but that central hemisphere was surrounded by a substantial ring of additional coral growth; we anticipated that the lowest parts of PBK-7 at the time survived the diedown that killed the others in the population, and that PBK-7 had subsequently grown back up. PBK-8 (Figure S38) seemed to be a bit better preserved than the others, and we hoped its record would fill in parts of the record rendered incomplete by erosion of parts of the other microatolls.

Indeed, the U-Th dates on all four slabs confirm our initial field interpretations: allowing for erosion of up to several outer bands on each slab, PBK-5, PBK-6, and PBK-8 all appear to have died in 1861 (Figures S35, S36, S38). PBK-7 experienced a large diedown in 1861, but grew back up for at least 30 years after that diedown (Figure S37). Although a survey of the outer ring of PBK-7 suggests the coral tilted slightly at some point since its death, the top of the central hemisphere was at the same elevation as the respective outer rings of PBK-5, PBK-8, and other *Porites* microatolls in the population, indicating it had not settled by a measurable amount, and indicating the central hemisphere had grown up nearly to HLS just prior to the diedown. (PBK-6 was ~8 cm higher, consistent with the ~10 cm elevation difference commonly seen between coeval *Porites* and *Goniastrea* microatolls.) The slab shown in Figure S37 has been corrected for the tilting inferred from the survey; after correcting for this tilting, we estimate the 1861 uplift at PBK-B by measuring the diedown on PBK-7, which is 30–35 cm.

Fossil microatolls PBK-10, PBK-11, and PBK-12 (Figures S40–S42) were sampled from a population of microatolls farther south at the PBK-C subsite. Our field interpretation was that these constituted a different generation than the fossil microatolls at the PBK-B subsite, but U-Th dating results indicate these three corals also died in 1861. PBK-10 was a *Porites* microatoll and PBK-11 was a *Goniastrea* microatoll several meters away, inferred to be from the same generation as one another. We sampled both, anticipating PBK-10 would yield a better paleogeodetic record, and PBK-11 would provide more precise age control. Indeed, the U-Th dates on PBK-10 are imprecise but the succession of diedowns suggests the coral died in 1861; the U-Th date on adjacent PBK-11 is precise and requires an 1861 death (Table S3). Nearby, PBK-12, another *Porites* microatoll, appeared similar but not identical to PBK-10, so we slabbed it as well, in case it would provide unique information. The U-Th date on PBK-12 is also consistent with a death in 1861 (Table S3). Given the overlap in ages between the fossil microatolls at PBK-B and PBK-C, the reason for the slightly different morphologies between the microatolls at the PBK-B site and those at the PBK-C site is unclear; it could be a result of higher erosion of the outermost rings on all the fossil microatolls at the PBK-B site.

Fossil microatoll PBK-3 was a substantially tilted but well preserved *Porites* microatoll at the PBK-A site. We initially chiseled off a piece during our visit in 2007 (Figure S31) to determine the age of the microatoll, and the U-Th dates suggested it died in 1861. At the time of our 2009 site visit, then, we knew that PBK-3 dated to 1861, but not yet knowing whether any of the other microatolls at the site would also date to 1861, we took a full slab of PBK-3, even though it was not in place. We subsequently x-rayed and analyzed two parallel slices from the PBK-3 slab (Figures S32–S33), as different diedowns were preserved on each slice. By matching the "1848" diedown on the two slices and by determining that the 2007 hand sample was barely younger than that diedown, we were able to correlate the banding across all three x-rayed slices. The dates and diedowns shown on Figures S31–S33 reflect our understanding of the coral based on all three slices collectively.

Fossil microatolls PBK-2 (Figure S30) and PBK-9 (Figure S39) were taken from another small population of *Porites* microatolls near the pre-2005 beach face at the PBK-A site. In the field, the two corals were inferred to be of the same age. We initially chiseled off a piece of PBK-2 during our visit in 2007 to determine the age of the microatoll; PBK-2 was chosen for this because it was small and easy to chisel. When we returned in 2009, we preferred to extract a slab from the adjacent PBK-9, which was bigger and more well preserved. At face value, the U-Th ages of PBK-2 and PBK-9 do not overlap, but our analysis of the PBK-9 slab (discussed below) suggests that the reported date for PBK-9 must be wrong; instead, the analysis supports our initial field interpretation that the two corals died at the same time.

The most compelling argument against the accuracy of the weighted-mean U-Th date for the outer preserved band of PBK-9 is that, if the AD 1880 ± 6 date is taken at face value, then the early 1861 diedown should be present 20 ± 6 annual bands prior to the outer preserved band. Given the elevations of PBK-9, PBK-7, and coeval microatolls from site PBK-B, the HLS immediately following the 1861 uplift should have been 30 cm lower than the outer rim of PBK-9 (compare Figures S43 and S44). In contrast, the oldest ~33 preserved bands on PBK-9 all extend higher than that level, yet no diedown within that period extends as low as the 1861 HLS on PBK-7. Indeed, as the preferred band ages are shown on Figure S39, the beginning of the "1861" band extends up to an elevation 29 cm below the slab's outer rim, which is barely permissible, given the lack of a diedown in that year: this is ~1 cm higher than the 1861 diedown on PBK-7, which falls within the natural variability in HLS seen at many sites [Meltzner and Woodroffe, 2015]. If the actual 1861 band occurred any later in the coral's growth history, as is suggested by the U-Th dates, it would require the early 1861 HLG to be higher in elevation, which would conflict with the elevation of the post-1861 HLS on PBK-7. We therefore assign banding dates on PBK-9 that minimize the misfit to the weighted-mean U-Th date while avoiding violating what we know about the post-1861 HLS on PBK-7. Lastly, in further support of our assigned ages for PBK-9 (as well as for PBK-7), we note that, as shown, both corals experienced a substantial diedown in mid-to-late 1877. A large diedown at this time is also observed in a coral from the Batu Islands [Philibosian et al., 2014], and it corresponds to the most extreme positive IOD event from at least 1846 until late 1961 [Abram et al., 2008]. With the banding ages fixed as shown in Figures S30 and S39, we infer that both PBK-2 and PBK-9 died in 1894 or soon thereafter. Although the cause of death for these young fossil microatolls is unclear, it is similar to the 1890 date of the outer preserved band of PBK-7.

With only a few exceptions, the diedowns on the PBK fossil microatolls are consistent. Starting with the 18th century, PBK-5, whose record goes back the farthest, recorded diedowns around 1751, and then in early 1760 and around 1800; PBK-6 recorded its earliest diedown in early 1800. The 1760 and 1800 diedowns likely correlate to diedowns seen in the older Simeulue corals. The portions of PBK-5 and PBK-6 from the decades after AD 1800 are highly eroded, and diedowns following 1800 on those two slabs would not necessarily be recognizable today. However, well preserved PBK-12 recorded diedowns in mid-1817 (ubiquitous on Simeulue), early 1824, mid-1825, mid-1829, early 1833 (ubiquitous on Simeulue), late 1837, early 1844, and mid-1850 (seen on a few corals from Simeulue). The 1833 diedown is seen on all fossil corals that were alive at the time at PBK, and the late 1837 diedown is also seen on PBK-6 and PBK-10. A diedown in mid-1846, which was widespread across Simeulue, is seen on PBK-6 and PBK-10, but is conspicuously absent on PBK-12. Diedowns in late 1850 occur on PBK-10 and PBK-11. Most of the corals died completely in early 1861; PBK-7 recorded a large diedown but survived to grow back upward. PBK-7 and PBK-9 recorded the large diedown in mid-to-late 1877, and then PBK-9 recorded additional diedowns around 1883 and 1888.

Corals at the PBK-B site record an average subsidence rate of 2.2 ± 0.7 mm/yr from 1751 until 1861 (Figure S44). That subsidence appears to have been fairly steady from 1812 onward, but we cannot preclude decadal-scale fluctuations in the rate prior to 1812. Corals at the PBK-C site suggest a subsidence rate of 4.6 ± 2.9 between 1833 and 1861 (Figure S45). Although this appears to be faster than the rate at PBK-B, we note that the error bars in the rates from the two sites overlap. The 30–35 cm coseismic uplift in 1861 was followed by rapid postseismic subsidence of ≥ 25 cm in < 14 years (Figure S44); after 1875, microatolls PBK-7 and PBK-9 suggest steady interseismic subsidence of 3.0 ± 4.2 mm/yr until at least 1894 (Figures S43–S44).

Text S8. Results from the Pulau Wunga (PWG) Site

Pulau Wunga ("Wunga Island") lies 14 km off the west coast of northern Nias Island and is 6 km long, elongated north-northwest to south-southeast. Prior to the 2005 earthquake, the island consisted of no fewer than ten islets, all interconnected by a living coral reef flat that nearly surrounded a shallow central lagoon (Figure S47). The island was uplifted 1.8 m in the 2005 earthquake, with 0.2 m of additional postseismic uplift by June 2006. Since the 2005 uplift, Pulau Wunga has been a single island. The central lagoon is still submerged at all times, albeit under shallower water than previously. The PWG site lies on the northern half of Pulau Wunga and includes portions of the central lagoon (Figure S47). We sampled two modern and two fossil microatolls at Pulau Wunga.

8.1. Modern Paleogeodetic Record at PWG

The primary modern microatoll from the PWG site, PWG-1, was a huge coral colony, more than 2.5 m tall and ~6 m in diameter, but it was irregular and lobate. It was a solitary modern microatoll in the lagoon. Although we had initially hoped to find a sequence of protected diedowns in the colony's interior, the only diedowns it recorded were in late 1994 and late 1997 (Figures S48 and S52), which is too short a record to provide useful information about pre-2005 interseismic subsidence. We attempted to sample another modern microatoll on the reef flat, PWG-4, but it also recorded no diedowns prior to 1994. Because PWG-4 did not contain any unique information, we did not analyze it further.

8.2. Fossil Paleogeodetic Record at PWG

In addition to the modern microatoll, we found two enormous fossil microatolls in the Pulau Wunga lagoon. PWG-2 was more than 2.5 m tall and ~7 m in diameter, whereas PWG-3, 550 m away in a slightly shallower part of the lagoon, was ~2 m tall and ~10 m in diameter. PWG-2 was radially symmetric, indicating it grew from a single coral colony, but PWG-3 was geometrically complicated, suggesting at least a possibility that it formed as a cluster of corals that grew together. In the field, we anticipated that these two corals were coeval, but we decided to slab both, as both were considerably eroded. We extracted and analyzed a full radial slab of PWG-2 (Figure S49), as well as a slab through the outermost 1.5 m of PWG-3 (Figure S50). We also took a small sample for dating from the geometrical center of PWG-3, in an effort to better understand the coral's growth pattern and to determine whether it would be worthwhile to return to extend the slab through the full radius. We will refer to the slab through the outermost rings of PWG-3 as slab PWG-3A, and the sample from the center of PWG-3 as sample PWG-3B.

The U-Th dates from PWG-2 and PWG-3A suggest both corals died in 1861. Both corals record an initial period of slow submergence, followed by more rapid submergence in their final decades of growth, as seen in the pre-1861 microatolls from southern Simeulue. PWG-3A is the better preserved of the two, so we will use PWG-3A to reconstruct RSL at the site (Figure S51). PWG-3A recorded diedowns in early 1791, mid-1817, early 1833, and mid-1846, the latter three of which are seen repeatedly on southern Simeulue and Bangkaru. The corals record a submergence rate of ~3.5 mm/yr prior to 1829 and a rate of ~8.5 mm/yr thereafter.

There are several ways we can estimate the 1861 uplift at Pulau Wunga. A conservative minimum estimate of 1861 uplift, based on the elevation difference between the top and bottom of the outer preserved band on PWG-3A, is ~30 cm. Based on the fact that PWG-2 and PWG-3 experienced large diedowns in 1861, the 1861 uplift was most likely comparable to or larger than the 1.8 m of uplift in 2005. If the 1861 uplift was sufficient to kill PWG-2 and PWG-3 entirely, then the uplift was 2 m or more. However, we cannot say with certainty that PWG-2 and PWG-3 were killed entirely: given the substantial erosion of both microatolls, if they had only died down partially and if a low outer ring had grown out for several years to decades after 1861, it is unclear whether we would be able to recognize that today. The best we can say with reasonable confidence is that the 1861 uplift was likely equal to or larger than the 2005 uplift.

The U-Th date from sample PWG-3B is AD 1533 ± 36, suggesting the center of the PWG-3 microatoll extends back more than three centuries from its 1861 death. Preliminarily, this suggests a longer recurrence interval between the pre-penultimate and penultimate large uplifts at Pulau Wunga, than between the penultimate (1861) and ultimate (2005) uplifts. However, we caution that the PWG-3 microatoll's surface morphology is complicated and it ought to be fully slabbed and analyzed, in order to adequately understand the site's RSL history. As of the time of writing, we have not returned to the site, but we recommend such an endeavor for future work.

Text S9. Results from the Afulu (AFL) Site

The Afulu site sits at the end of a peninsula jutting out into the Indian Ocean along the west coast of northern Nias, 17 km east of Pulau Wunga, near Afulu village (Figure S53). The site rose 2.3 m in the 2005 earthquake, with 0.4 m of additional postseismic uplift by July 2006. The AFL site is 18 km southeast of continuous GPS station LHWA of the Sumatran GPS Array (SuGAr). By comparison, LHWA recorded 2.88 m of coseismic uplift in the 2005 earthquake [Konca et al., 2007], but that uplift was followed by 0.13 m of postseismic subsidence by the beginning of July 2006 [Feng et al., submitted]. Interestingly, the direction of postseismic vertical deformation at the two sites differed (AFL went up while LHWA went down), but by July 2006, the net change at both sites was ~2.7 m of uplift.

A grove of coconut palms was planted in a grid along the western side of the peninsula in the early part of the 20th century, according to villagers (Figure S53). In the ensuing decades, as a result of gradual subsidence, the lowest trees died from salt-water incursion during high tides. Natawidjaja et al. [2007] provide an aerial photo (their figure 2a) of the dead tree stumps in the intertidal zone in January 2005, following decades of interseismic subsidence. An accompanying photo (their figure 2b), taken in May 2005 after the coseismic uplift, shows the coconut palms and much of the coral reef high and dry, even at high tide. We sampled one modern and four fossil corals from the reef at Afulu.

9.1. Modern Paleogeodetic Record at AFL

The modern microatoll from the AFL site, AFL-1, started growing around 1940 and recorded its first diedown in late 1956, but it mostly died in late 1997, except for a few isolated knobs that survived until 2005 on the top and the sides of the coral. During the 2005 earthquake, AFL-1 was uplifted, tilted, and died completely. To reconstruct the coral's original horizontality, we carefully surveyed the 1997 and earlier concentric rings, which were even and well preserved all around AFL-1. The slab is shown in its restored, original, untilted orientation in Figure S54. Because the slab does not contain any post-1997 growth, we determined the slab's original elevation (Figure S59) by surveying the 2005 and 1997 concentric rings on numerous in situ modern microatolls at the site, and then by setting the pre-1997 HLG elevation on AFL-1 equal to the pre-1997 HLG elevation on the in situ microatolls. AFL-1 records diedowns in late 1956, late 1961, late 1972, late 1975, late 1978, late 1982, late 1986, late 1991, late 1994, and late 1997. Except for the 1972 diedown, all of these are seen on Simeulue [Meltzner et al., 2010, 2012]. AFL-1 records rapid interseismic submergence of 9.9 mm/yr from 1956 to 1997, which, adjusting for 20th-century sea-level rise, indicates about 7.9 mm/yr of tectonic subsidence.

9.2. Fossil Paleogeodetic Record at AFL

Midway out on the Afulu peninsula, we found a very well preserved fossil microatoll, AFL-3, mostly buried in the soil (Figure S55). Of particular note is this coral's minimal erosion: in the field, the outer double rim appeared especially well preserved, and in the slab cross section, the outer surface is nearly perfectly parallel to banding. U-Th analyses suggest the outer band dates to AD 1836 ± 21, which would be consistent with a death in the January 1843 earthquake, but not with a death in 1861. If we assume AFL-3 died in January 1843 and has sustained less than a few millimeters of erosion of its outer edge, then earlier diedowns on this coral occurred in mid-1817 (seen repeatedly elsewhere), in early 1828, at the beginning of 1833 (seen repeatedly elsewhere), and in early 1840. The agreement of the 1817 and 1833 diedown dates with dates of diedowns elsewhere supports the interpretation that this coral died in early 1843. The minimum uplift necessary to kill what was then the outer living band of AFL-3 would have been 17 cm. Interseismic submergence prior to 1843 was rapid, and there is a suggestion of an increase in the rate after 1833; nonetheless, the brevity of the time series results in large errors in the rates both before and after 1833 (Figure S58), precluding conclusions about changes in the rate over time.

In addition to slabbing AFL-3, we chiseled two coral samples from amidst the grove of dead coconuts just to the west (Figure S53). AFL-4 was a mushroom-shaped (hemispherical) fossil *Goniastrea* coral (not a microatoll) that was found standing on its thin stalk; because of its seemingly precarious position, it is unlikely to have been rolled to that location by a tsunami, and it is more likely to have been in place, killed by tectonic uplift. Our field interpretation was that AFL-4 was killed by the same uplift that killed AFL-3; the U-Th analyses indicate that its outer preserved band dates to AD 1843 ± 2 (Figure S56). Nearby, an overturned *Porites* microatoll, AFL-5, dated to AD 1856 ± 11 (Figure S57). Together, AFL-3 and AFL-4 offer compelling evidence for uplift around 1843, presumably associated with the 1843 earthquake. AFL-5 is more consistent with a death in 1861, but whether it died from uplift or a tsunami is unclear.

Unfortunately, during data analysis we discovered a surveying irregularity at this site. We suspect that for some points, the reflector height was entered incorrectly into the total station, causing all points on AFL-3 to be systematically recorded too high, by as much as 50 cm. As a result, the absolute elevations for AFL-3 (in Table S3 and on Figures S58 and S83) are suspect.

Farther out on the peninsula, we found a large population of large fossil microatolls (Figure S53). We slabbed one of these, AFL-2; U-Th dating suggests it died early in the 19th century. This may hint at an uplift then. However, given the surveying irregularity on AFL-3, and having so far slabbed only a few imprecisely dated microatolls on Nias that span the period of AFL-2, we will defer discussion and interpretation of the AFL-2 record to a later paper.

Text S10. Results from the Pulau Senau (PSN) Site

Pulau Senau ("Senau Island") lies 4 km off the north coast of Nias and is 4 km long, elongated west-southwest to east-northeast. The PSN site is near the eastern tip of Senau Island (Figure S60), 23 km due north of the Afulu site and 16 km northeast of the LHWA GPS station. The site was uplifted 1.5 m in the 2005 earthquake, with little vertical change between site visits in May 2005 and June 2006. We sampled one modern and two fossil microatolls at Pulau Senau.

10.1. Modern Paleogeodetic Record at PSN

The modern microatoll from the PSN site, PSN-1, first recorded a diedown in late 1982, which was followed by a second diedown in late 1997 and complete death due to uplift in 2005 (Figures S61 and S65). This was the longest RSL record we found on a modern microatoll at the PSN site, but unfortunately it is too short (with too few diedowns) to provide useful information about pre-2005 interseismic subsidence—particularly because the coral may not have been close to HLS before its initial diedown in 1982 or after the severe IOD-induced diedown in 1997.

10.2. Fossil Paleogeodetic Record at PSN

The primary fossil microatoll from the PSN site, PSN-2, grew in the first half of the 19th century. Two parallel slices from a single slab were x-rayed and analyzed, because of concerns that the banding was difficult to trace. We focused our analysis efforts on slice *a* (Figure S62), which had clearer banding overall, but we also analyzed the older portions of slice *b* (Figure S63), to ensure that we arrived at the same count, on each slice, of the number of annual bands between corresponding diedowns. Banding was particularly difficult to follow in the younger portions of slice *b*, so we did not attempt to show that portion of the banding, and we rely on slice *a* instead.

Our preferred interpretation for the age of PSN-2 reflects the U-Th dating results, as well as the relative timing of individual diedowns. As shown in Figures S62–S63, we infer diedowns in early 1814, mid-1817, early 1824, and early 1833, with an outer preserved band dating to 1848. Although the U-Th dates permit an age assignment for the outer preserved band that would be a little closer to 1861, such an age assignment would result in less consistency between the dates of the more prominent diedowns on PSN-2 and the dates of diedowns at nearby sites.

If our preferred age interpretation is correct, no diedowns occur on this coral after 1833. This not only implies no uplift at this site in 1843, but the lack of a mid-1846 diedown, as seen at PWG, as seen to the east (see Text S11), and as seen repeatedly on Simeulue and Bangkaru, suggests subsidence (of at least a few centimeters) occurred at PSN in 1843; this subsidence would have lowered the microatoll with respect to RSL and allowed for unrestrained upward growth of PSN-2 in its final 15 years. If our preferred age interpretation is correct, however, it remains unclear why the coral apparently died soon after 1848. PSN-2 appeared reasonably well preserved in the field, making it unlikely that the coral had survived until 1861 but had subsequently sustained complete erosion of its outer 12 bands.

Alternatively, if PSN-2 is 10 years younger than suggested by our preferred band dates on Figures S62–S63, what is currently labeled as "1833" may instead be the 1843 band, and the diedown at the beginning of that year may reflect 6–8 cm of coseismic uplift. This would solve the problem of the apparent missing bands after 1848, but it would complicate interpretation of the earlier diedowns. This is the primary reason we do not prefer a younger age interpretation, but we cannot absolutely preclude the younger interpretation, and we cannot preclude minor uplift at the PSN site in 1843. For future work, we suggest returning to the site to slab a coeval microatoll, in the hopes of better understanding the 19th century RSL record at Pulau Senau.

As at the AFL site, interseismic submergence was rapid, and there is a suggestion of an increase in the rate after ~1830 (assuming our preferred age interpretation). However, there are large errors in the rates both before and after 1830 (Figure S64), precluding conclusions about changes in the rate over time.

We also slabbed an older microatoll at the site, PSN-3, and Briggs et al. [2008] sampled a microatoll from a well ~300 m away, SEN-2; both of these turned out to be mid-Holocene in age. PSN-3 dated to 6385 years before AD 2007, or about 6330 years BP (Tables S2–S3; Figure S60), whereas SEN-2 dated to ~4000 years BP [Briggs et al., 2008]. Compared to the elevation of the outer rim of PSN-1, the outer rim of PSN-3 was ~64 cm higher, and SEN-2 was ~104 cm higher. Overall, the lack of a consistent age–elevation trend between samples PSN-3, SEN-2, and PSN-1 is consistent with the findings of Briggs et al. [2008] that the mid-to-late Holocene RSL history of the island is dominated by elastic deformation related to strain accumulation and release along the megathrust, and that longer-term rates of upper-plate deformation and glacial isostatic adjustment (GIA) are remarkably low.

Text S11. Results from the Muzoi Ilir (MZL) Site

The Muzoi Ilir site sits on a peninsula 5 km northeast of the mouth of Sungai Muzoi ("Muzoi River"), 3 km west of Hiligeo Afia village, and 8 km east of the PSN site, along the northern coast of Nias (Figure S66). We named the site after a feature on a nautical chart published by the Hydro-Oceanographic Office of the Indonesian Navy, but we have not been able to find that or any similar name on other published or unpublished maps. The site was uplifted

0.8 m in the 2005 earthquake, with 0.2 m of additional postseismic uplift between May 2005 and June 2006. We sampled one modern and three fossil microatolls at the MZL site.

11.1. Modern Paleogeodetic Record at MZL

The modern microatoll from the MZL site, MZL-1, recorded its first diedown mid-1970, following which it recorded additional diedowns and gradual interseismic subsidence until its death due to uplift in 2005 (Figures S67 and S71). Although a mid-1970 diedown is not seen elsewhere, all subsequent diedowns on MZL-1 were: late 1972, late 1978, late 1982, late 1991, and late 1997. MZL-1 records interseismic submergence of 4.5 mm/yr from 1970 to 1997, which, adjusting for 20th-century sea-level rise, indicates about 2.5 mm/yr of tectonic subsidence.

11.2. Fossil Paleogeodetic Record at MZL

Over a distance of less than 100 m at the MZL site, we found two generations of fossil microatolls clustered together at roughly similar elevations, and we slabbed three microatolls from those populations (Figure S66). The two younger microatolls apparently died in 1861. MZL-3 (Figure S68) was a *Porites* and MZL-4 (Figure S69) was a *Goniastrea*, and they had analogous morphologies, suggesting they were coeval. U-Th analyses suggest the outer band of MZL-3 dates to 1851 ± 29, while the outer band of MZL-4 dates to 1860 ± 7. MZL-3 records diedowns in early 1824, early 1833, and mid-1844, whereas MZL-4 records diedowns in early 1833, early 1838, mid-1844, and mid-1846. Except for the 1838 and 1844 diedowns, these are all seen elsewhere on Nias; the early 1838 diedown may be what we called a late 1837 diedown at PBK, and the mid-1844 diedown may be what we called an early 1844 diedown at PBK. The minimum uplift necessary to kill what was the outer living band of MZL-3 in 1861 would have been 35 cm. We estimate interseismic submergence to have been 4.4 mm/yr from 1823 until 1861 (Figure S70).

Nearby, the biggest and oldest of the slabbed microatolls, MZL-2, appears to have died late in the 18th century, or at the beginning of the 19th century. Although the records of MZL-2 and AFL-2 surely overlapped one another, given the proximity of their ages and the length of each record (more than 80 years in each case), it is not clear whether they died synchronously. Meanwhile, on Simeulue, there is compelling evidence against uplift around the beginning of the 19th century. Since we have so far slabbed only a few imprecisely dated microatolls on Nias that span that period, we will defer discussion and interpretation of the older corals to a later paper, by which time we hope to have more microatoll slabs collected from Nias.

Text S12. Results from the Bawelowalani (BWL) Site

The Bawelowalani site sits on a peninsula, Tanjung Saetsyu, along the west coast of southern Nias, 67 km southeast of Afulu, near Bawelowalani village. The site was uplifted 1.3 m in the 2005 earthquake. We sampled one modern and two fossil microatolls at the BWL site.

12.1. Modern Paleogeodetic Record at BWL

The modern microatoll from the BWL site, BWL-1, first recorded a diedown in late 1966. The coral was still small at that stage, ~25 cm in diameter and ~15 cm tall, and it died down nearly to its base. It is unclear what caused such a large diedown on this coral at a time when no other corals on Simeulue, Bangkaru, or Nias were affected, but we speculate that the coral may have been moved. This diedown was followed by substantial upward growth until late 1991, when the next diedown occurred; a third diedown occurred in late 1997, and then the coral died completely due to uplift in 2005 (Figure S72). Because we consider the 1966 diedown suspicious and because the record of RSL on this coral is otherwise so short, we cannot use it to reliably estimate a rate of interseismic submergence.

12.2. Fossil Paleogeodetic Record at BWL

The only fossil microatoll at site BWL from which we extracted a full slab was BWL-2. BWL-2 was a solitary microatoll, without any obvious contemporaries, and was noticeably more weathered than other microatolls at the site, but still in good enough condition to warrant a slab. U-Th dates suggest BWL-2 died near the beginning of the 19th century, perhaps coincident with microatoll AFL-2 or MZL-2 from northern Nias. As stated earlier, we will defer interpretation of these older microatolls to a later paper, and we will not discuss them further here.

In addition to BWL-2, we found a large population of well preserved fossil microatolls that were morphologically similar to and at the same elevation as one another, suggesting they were all from the same generation. Unfortunately, we had only half a day at the site, and these corals were too far from water to be slabbed with our hydraulic chainsaw. As a consequence, we settled for chiseling a large piece of the outer rim off of one of these corals, BWL-3, and then we sliced and x-rayed the resulting chunk of the outer rim (Figure S73). Regrettably, the U-Th dates are imprecise, and given the small piece of coral in our sample, the coral's date of death could be either 1843 or 1861. We recommend returning to the site at high tide, and with sufficiently long hoses and sufficiently powerful pumps, to fully slab a microatoll from the BWL-3 generation, in order to better understand the 19th century RSL record and uplift history at the site.

Text S13. Results from the Lagundri (LAG) Site

The Lagundri site lies on the east side of Teluk Lagundri ("Lagundri Bay"), the westernmost embayment on the south coast of Nias, and near Lagundri (or Lagundi) village (Figure S74). It is 28 km south-southeast of the BWL site. Despite extensive searching, we found only a few small (20–30 cm diameter) *Goniastrea* and no *Porites* microatolls that had been alive just before the 2005 earthquake, perhaps because a stream emptied into the bay in the middle of the site and inhibited coral growth nearby; this scarcity of modern microatolls at the site limited direct measurements of 2005 uplift there. Adjusting for the ~10-cm higher growth of *Goniastrea* microatolls, the few samples we found suggest the 2005 uplift at LAG was 0.4–0.5 m, although the uncertainty is high. Separately, we can estimate the 2005 uplift at the LAG site by interpolating between two nearby measurements: at Lagundri village, 2 km to the west-northwest, Briggs et al. [2006] estimated 0.8 m of uplift, whereas at Teluk Fohili, 3 km to the east, the 2005 uplift was 0.1 m (updated from Briggs et al. [2006], considering sea level anomalies). If the uplift varied linearly between these two sites, it would have been ~0.5 m at the LAG site. All things considered, we conservatively infer the 2005 uplift at LAG was between 0.3 and 0.6 m. We sampled five fossil but no modern microatolls at the LAG site.

13.1. Fossil Paleogeodetic Record at LAG

Most of the microatoll slabs at the LAG site came from the north side of the stream and beach that bisect the site, but one slab came from a field of microatolls southwest of the stream. Microatolls LAG-1 (Figure S75) and LAG-2 (Figure S76), both north of the stream, were at similar elevations but had slightly different morphologies from one another, so we slabbed both. From southwest of the stream, we collected a slab from microatoll LAG-4 (Figure S79), as it also had a unique geometry.

Microatolls LAG-3A (Figure S77) and LAG-3B (Figure S78) were more complicated. In the field, we mistakenly believed that they were a single microatoll, despite irregularities in their plan-view geometries. Because of these irregularities, we decided to take two slabs from this inferred microatoll, slabs LAG-3A and LAG-3B. Unfortunately, the initial slab of LAG-3A was not sufficiently long to clear up our points of confusion, so we returned in 2009 to extend the LAG-3A slab. It was only after collecting the LAG-3A extension (Figure S77) that we realized the LAG-3A and LAG-3B slabs had come from different microatolls, and that a portion of the LAG-3B coral had grown over LAG-3A, hiding the boundary between the corals.

The U-Th dates and diedown correlations suggest LAG-1, LAG-2, LAG-3A, and LAG-4 all died in 1861. LAG-3A, which goes back the farthest, records diedowns around early 1750, late 1760, early 1768, early 1833, and mid-1846; evidence for several intervening diedowns was likely destroyed by erosion. LAG-1 records diedowns around early 1807, mid-1817, mid-1826, early 1833, early 1845, mid-1847, and late 1852. LAG-2 records diedowns around early 1813, mid-1817, early 1833, and mid-1846. After recording an early history of RSL, the inner block of slab LAG-4 overturned, experienced out-of-plane growth for a poorly determined number of years (the duration is poorly determined because the banding cannot be counted), and then recorded diedowns around mid-1817, early 1829, early 1833, early 1842, and mid-1850. It is unclear why LAG-1 appears to record a diedown in mid-1847 instead of mid-1846, but this may be an artifact of a one-year band-counting error: the annual banding is less distinct in the part of LAG-1 immediately surrounding the band labeled “1845” in Figure S75, and several of the bands we traced in that part of the coral may each reflect less than a full year of growth. If this indeed occurred, the “1833” and earlier labels in Figure S75 would still be correct, but the “1848” and younger labels would be off by one year.

The U-Th dates on LAG-3B are precise and require that the coral lived through 1861. The intervals between successive diedowns on LAG-3B support such an age interpretation: taking the U-Th dates at face value (but at the early limit of their ±6 year reported error), the slab records diedowns at the end of 1832 (or the beginning of 1833), in mid-1846, in late 1852, in early 1861, and in mid-1877. The 1832 (or 1833) and 1846 diedowns are nearly ubiquitous on other microatolls; the 1861 diedown reflects coseismic uplift; and the 1877 diedown coincides with large diedowns on Bangkaru (Text S7) and in the Batu Islands [Philibosian et al., 2014]. What eventually killed LAG-3B soon after 1899 is unclear: it may be related to the deaths of corals PBK-2, PBK-7, and PBK-9 on Bangkaru; it may be related to the 1907 earthquake; or the death of this solitary microatoll may have nothing to do with tectonics or RSL change.

The LAG-3B microatoll is anomalous, and in order to calculate the 1861 uplift at the site, we must first understand what happened to LAG-3A and LAG-3B before, during, and after the 1861 earthquake. Given the observation that LAG-3B recorded the diedowns in 1833 and 1846, it is clear that the microatoll was growing up to HLS in the decades before 1861; a survey of all the microatolls at the LAG site, however, reveals that LAG-3A and LAG-3B settled and tilted at some time. In particular, as we observed the corals in the field, the HLG from the bands immediately preceding 1861 was ~10 cm lower on LAG-3A and ~24 cm lower on LAG-3B than on LAG-1 or LAG-4. Another important observation concerns the height of the outer living band on each microatoll at the time of the earthquake. At the beginning of 1861, the outer living band on LAG-1 and LAG-3B would have extended ~30 cm lower than the HLG, and the other corals were even shallower: the outer living band was ~20 cm tall on LAG-3A and LAG-4, and it was only ~10 cm tall on LAG-2. Thus, unless one of the microatolls settled at the time of shaking, a mere ~30 cm of uplift would have been sufficient to kill all the LAG microatolls entirely.

Why did LAG-3B survive the 1861 diedown, when all other microatolls at the site died? Our hypothesis is that LAG-3A and LAG-3B settled and tilted at the time of shaking in 1861. This allowed the lowest part of LAG-3B to survive the uplift. LAG-3A, however, was ~10 cm shallower before the earthquake and settled by a smaller distance, so LAG-3A did not survive. The coseismic settling and ensuing postseismic subsidence created accommodation space that allowed LAG-3B to grow upward and over itself and over the adjacent LAG-3A. This unusual pattern of growth, in which LAG-3B grew up and over LAG-3A after LAG-3A died from uplift, is what confused us in the field and led us to believe that LAG-3A and LAG-3B were a single, albeit geometrically irregular, microatoll.

To calculate the uplift in 1861, we measure down from the pre-1861 HLG on LAG-1 and LAG-4. Although LAG-3B tilted and settled at the time of shaking (and hence the pre-1861 HLG on LAG-3B is no longer at its original elevation), the post-diedown HLS on LAG-3B is a reliable reflection of RSL immediately after the uplift. Hence, we can estimate the 1861 uplift at LAG as the difference between the pre-diedown HLG on LAG-1 and LAG-4 and the post-diedown HLS on LAG-3B: 28 cm (Figure S80). We then add 6 cm to account for the estimated erosion of the outer rims of LAG-1 and LAG-4; this yields an estimate of ~34 cm of uplift in 1861 at LAG.

From just after the 1817 diedown until 1861, microatolls LAG-1 and LAG-4 record subsidence at 2.2 mm/yr. LAG-2 has a similar RSL history, but it is shifted lower, by ~7 cm, presumably due to settling of the coral. From the 1817 diedown back in time, LAG-1 appears to record a lower RSL history than the other two corals. The reason for this is puzzling: we propose that LAG-1 may have been moved shortly after 1817, but we concede that there is no clear or completely satisfying explanation for the discrepancies in 1817 and earlier. Hence, we do not attempt to interpret the RSL history or estimate rates of RSL change prior to 1817.

The 1861 uplift was followed initially by at least 5 cm of postseismic subsidence and later by interseismic subsidence (Figure S80). We estimate an interseismic subsidence rate of 4.3 mm/yr from 1866 to 1899, but to the extent that we have underestimated the amount of postseismic subsidence, the ensuing interseismic rate might be biased high.

Text S14. Modeling Methods

We employed elastic dislocation modeling in an effort to explain the various rate changes inferred from our corals. We developed back-slip models [Savage, 1983], incorporating a variably dipping fault geometry that approximates the Slab 1.0 model [Hayes et al., 2012] for this section of the megathrust, and which fits the depth of aligned microseismicity beneath southeastern Simeulue recorded by an ocean bottom seismic (OBS) array [Tilmann et al., 2011]. The model slab extends to a depth of 100 km (Figure S87); all model depths hereafter will be expressed relative to sea level. We assumed a subduction (convergence) rate of 40 mm/yr, based on the rate reported by McNeill et al. [2014] for this section of the subduction zone.

We attempted to model the observed variations in interseismic rates as consequences of changes in the locking depth along the megathrust. Separately for Simeulue and for Bangkaru, we considered a range of plausible forward models. Because the southern Simeulue sites are roughly equidistant from the trench but experienced different subsidence rates at different times, we tried to explain the observations by modeling different along-strike variations in the locking depth at different times. In this manner, for any snapshot in time, we would be required to explain all the southern Simeulue rates with a single 3-dimensional locking geometry, but for a different decade or century, a different locking pattern might be required to explain the data. The Bangkaru site is sufficiently far from other sites that we modeled the rates there independently, considering changes only over a 2-dimensional profile perpendicular to the trench.

To test for along-strike variations in the locking depth under Simeulue, we divided the model fault into sections, each with a different locking depth. In all iterations of the model for Simeulue, we fixed the coupling (locking) ratio along the portion of the fault shallower than 18 km at 0.4; deeper than that, various patches along the fault were assigned either as fully locked (back-slipping at the subduction rate) or as creeping. One sample geometry is shown in Figure S88; this example illustrates a model with a locking depth change from 50 km in the northwest to 25 km in the southeast.

For each configuration of along-strike locking depth change, we calculated an along-strike surface uplift rate profile for a hypothetical row of surface points located 110 km from the model trench. This is the approximate distance from the trench (as defined by Bird [2003]) of the four southern Simeulue coral sites for which we have interseismic rates (Table S4). These surface uplift profiles were calculated as deformation due to a dislocation in an elastic half space [Okada 1985, 1992].

From Table 2, we defined four time periods on Simeulue, and we attempted to model the interseismic subsidence rates at three sites during each time period. From the fossil microatoll records, we modeled the rates at sites SMB, UTG, and LBJ, which are the best constrained. We divided the fossil microatoll records into the periods pre-1819 (going back to the beginning of the microatolls' records), post-1839 (through 1861), and a transition period between 1819 and 1839; during this transition, site SMB had already switched to a faster rate, but the other sites had not.

From the modern (pre-2005) microatoll records, we modeled the rates at sites SLR, UTG, and LBJ, which are the best constrained for that period. Sites SLR and SMB are only 8 km apart.

In an attempt to model the rate variations at Bangkaru, we used similar back-slip and elastic dislocation models as described for Simeulue. Specifically, the same fault geometry and subduction rate were incorporated into the model. However, considering that the Bangkaru site is farther from the trench (Table S4) and is therefore less sensitive to locking patterns near the trench, we simplified the model by eliminating the shallow region of partial coupling and instead extended the fully locked patch all the way to the trench. To start, we produced a set of interseismic surface uplift rate profiles for various downdip limits of locking, to compare with the fossil and modern rates estimated at the Bangkaru site. In particular, we wished to see whether we could fit the rapid interseismic uplift at the PBK site between 1966 and 1981 with conventional back-slip models.

We also used elastic dislocation modeling to predict deformation related to a hypothetical slow slip event (SSE) under or near Bangkaru. We modeled the surface displacements from an SSE as the superposition of (*a*) deformation from steady creep at depth and (*b*) deformation from thrust slip at greater than the plate convergence rate on a patch within the otherwise locked zone. The idea here was to see if we could fit the 1966–1981 uplift rate with a SSE superimposed on the conventional back-slip model, while fitting the subsidence rates from all other time periods at the PBK site with no SSE but with all other conditions the same.

Modeling results and interpretations are discussed in the main text.

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Appendix S1. Selected Primary Historical Accounts

1843 Historical Account #1

R. Baird Smith (1845), Register of Indian and Asiatic earthquakes for the year 1843, *J. Asiatic Soc. Bengal*, 14 (2), 604–622.

pp. 604–609:

3. *Earthquake of the 6th January, 1843*.—The greatest force of the shock of the 6th January, so far as our information extends, was felt at Pulo Nias[1], in the vicinity of Java and Sumatra. For the following extract from the "Singapore Free Press," detailing the effects of the earthquake, I am indebted to H. Cope, Esq.

Singapore. Below will be found an account of an earthquake at Pulo Nias, translated from the "Java Courant," which we have received from our correspondent. It will be observed, that this earthquake occurred about the same time with the shocks which were experienced in Manilla, Singapore and Penang; but that it was of a much more violent nature, and attended with disastrous circumstances, which were happily unknown in other instances. In this case the phenomenon partook of all those fatal and violent effects which have usually been the accompaniments of similar convulsions of the earth in Java and Sumatra.

Account of an Earthquake at Pulo Nias.

(Translation from the Java Courant, April 5th, 1843.)

Ignorant of the dismal scenes on which it would rise next morning, the sun set peaceably behind the Goenong (*mountain*) Sie Foli[2], (Island of Nias) on the evening of the 5th of January last.

At 6 p.m. the Thermometer (Fahrenheit) marked 83°, the sky was clear, the sea calm, the air pleasant and mild, only a breeze from the Westward (a circumstance of rare occurrence in these parts) was felt.

The inhabitants of Nias, not aware of the fate that awaited them, were enjoying the repose of sleep, when at or about midnight they were roused by heavy shocks of the earth, which at first were felt in a slight degree from the wind shifting to the Northward, but became every moment more violent; so that no fixed direction could be given to them, the shocks subsiding into a complete trembling of the earth, so that at every instant it was expected the whole Island would disappear.

The shocks continued without intermission during nine minutes, the ground was moved up and down, like the rocking of a swing; to stand up or to walk was alike impossible; houses were destroyed, burying beneath their ruins the ill-fated inhabitants.

A portion of the Mount Horiffa, close to Goenong Sie Foli, together with the fortifications of the Benting and the other Government buildings, with the exception of the barracks and Commandant's house, were totally destroyed; Coco and other large trees which for upwards of a century had withstood the hand of Time, were torn up by the roots, and the ground divided itself, shewing deep yawning chasms from which trickled a blackish frothy liquid.

No subterraneous noises were heard, being probably drowned by the dreadful din of falling mountains, houses and trees, joined to the thrilling shouts of the population.

About nine minutes passed in the fear of immediate destruction, the inhabitants began gradually to recover from the trance in which they lay plunged by this sudden calamity, people appearing from beneath the ruins of a house, or from an abyss into which they had been plunged; the one to save an aged mother, the other his helpless child.

The dreadful scene was lit up by the most beautiful sky and sparkling stars. Not long the unfortunate Islanders were permitted to exult in the hope of their miraculous escape. Again, the earth began to tremble, and repeated shocks were felt with new force. Suddenly a tremendous wave rose from the South-East, and with awful noise, spreading itself over that part of the Coast, bore every thing before it, sweeping away men, women, cattle, houses, and even whole villages; so that in a single moment, the same spot where cattle were grazing, had become the abode of fishes.

The large Campong Mego, about one Dutch mile, South of Goenong Sie Foli, was entirely washed away by the wave; and many days afterwards the dead bodies of the victims of this woeful destruction might be seen on the beach.

The same wave penetrated into the neighbourhood of Goenong Sie Foli with such violence, that the prows lying in the river were thrown upon the shore, 100 or 160 paces from their anchorage; among the number was the Government Cruising Schooner, No. 23. The new Bazar, consisting of wooden houses, and situated on the left side of the river, was also entirely washed away. The inhabitants who escaped fled to the Benting, 60 or 100 feet above the sea, to implore the succour of others as miserable as themselves.

This phenomenon continued until half-past four in the morning, the shock being felt at intervals of two minutes, when another earthquake was experienced, which was more violent than the first one, and continued for about six minutes. The shock generally came from the West, going to the North, changing however directly to the South. The trembling of the ground, although more slightly, was felt for several days afterwards.

The authorities here have immediately caused the necessary measures to be taken, and despatched a Government vessel to give assistance to the unfortunate inhabitants of the island of Nias.—D. F. S.

Padang, 23rd March, 1843.

———

Pulo Nias, the seat of the catastrophe just detailed, is a small island off the West Coast of Sumatra, in about 2° N. Lat. and 98° E. Long. The intensity of the Earthquake, however great in Pulo Nias, would appear to have diminished much at a short distance from it, since no notice of its effects on the adjoining coast of Sumatra is given, and from the silence of the writer of the above account, we are led to infer that the shock if felt at all at Padang, was there very slight.

Pursuing a North Easterly direction, this same Earthquake was experienced at Singapore and Penang. The following extract from the "Penang Gazette," details the effects of the shock at these two places.

"We noticed in our paper of the 7th instant, that a shock of an Earthquake had been experienced here about half-past 12 on the morning of the 6th, and we observe from the "Singapore Free Press" of the 12th, that a shock had been felt there precisely at the same time. In both places it was very slight, but here more generally, and on the hill at least, more severely felt than at Singapore. It is rather remarkable that on the 8th, when we had a repetition of the Earthquake about 2½ p. m. the shocks on that occasion were also more distinctly felt on the hills than in the valley. The oscillations were in both places of very short duration, and in Penang, as far as we can learn, the direction was from South to North or the contrary, but at Singapore it is stated to have been from East to West. For some time preceding this subterraneous commotion, the weather at Singapore had been unusually dry and hot for the season, the atmosphere clear, and the wind from the North East, and nothing indicated a change, until half an hour before the shock, when the heavens became 'quite black and chilly.' Here also it was preceded by the same kind of weather, which however is usual with us at this season, but no sudden change or phenomenon of any kind was noticed immediately to precede the shock, excepting that, as we have learned, the rats in a house in town were heard to be particularly noisy and riotous about the roof. In both places, however, a marked change followed the convulsion. At Singapore, at 7 a. m. the following morning, heavy rains set in, and continued unremittingly for eleven days; and in Penang we experienced for several successive days sudden gusts of wind interrupted by calms, and in the evening squalls from the N. and N. E. with heavy clouds, rain and thunder in these directions, no rain however fell upon the Island, excepting a short partial shower on the 15th, and the weather has again resumed its dryness and clearness. At this time not a blade of grass is to be seen, and vegetation of every description is suffering excepting where water is applied.

"Shocks of Earthquakes have on several occasions been felt at Penang; within the last ten years we have had four different shocks, and with the exception of the last, they have always happened during the latter months of the year. The first took place in November 1833, the second in August 1835, the third in September 1837, and the fourth on the 6th instant, as above stated. It appears therefore that here they occur periodically, and that the last interval has been more than double the usual length. Of these, the shock in September 1837, was, by all accounts, the most severe, and the oscillations, as in the present case, are said to have come from South to North, and to have lasted full a minute and a half. It is said that on that occasion, several herds of cattle in the neighbourhood were observed running in the utmost confusion in all directions, that lamp and picture-frames oscillated, that the Roman Catholic Church bell rang of its own accord, that quantities of large shot piled up in the Fort were thrown down and scattered about, that a stone wall of a substantial building in town was rent, and the whole inhabitants were thrown into a state of consternation. The shipping in the harbour did not experience this shock, nor did the sea appear agitated; five days subsequently however another smart shock was felt, and was followed by a very heavy squall from the N. W. and great agitation and rise of the sea in the harbour. The tide overflowed the Northern beach, and flooded the compounds and lower rooms of the houses in the neighbourhood. The convulsion was experienced at the same time at Achen and along the Pedier Coast, and it is said that these places sustained considerable damage. By the late shock a clock in town was stopped, and some felt a dizziness in the head and a sensation like sea-sickness, but we have not heard of any other phenomenon attending this Earthquake. It may be that neither this shock nor any of the previous ones we have noticed are to be supposed the effects of convulsions taking place immediately below us, but to have been transmitted from some neighbouring region within the range of Earthquakes, such as Sumatra. The recent one may be described as having been a mere tremor of the ground, more than a shock."—*Penang Gazette, 28th January, 1843*.

From the facts now detailed, it appears, that the point of greatest intensity of the shock of the 6th January 1843, was in the immediate vicinity of, if not directly beneath, the island of Pulo Nias. The south coast of the island suffered most, since it was upon it that the destructive wave first broke. The facts stated are not sufficient to warrant any conclusion as to the cause of this great wave; it may have arisen from violent volcanic action in the adjoining bed of the sea, or it may have been the reflux of a wave generated by the sudden upheavement of the coast of the island itself. In both cases it is probable, the sea would first have receded from, and then returned in force upon the coast, and in the latter part of the upheavement would have remained, but no indication of any such phenomena are given, and the point must remain an undecided one.

The general direction of the shock was from South-West to North-East; from the relative geographical positions of Pulo Nias and Singapore, the direction in the latter island would be from West to East, just the contrary to that specified in the extract above given; in Penang, on the other hand, the course would be from South to North, as correctly stated by the writer in the "Penang Gazette."

Indications of atmospheric disturbance accompanied the shock at Singapore and Penang, and most probably at Pulo Nias also, although it is not so stated in the published notices. At Singapore, nearer to the focus of the shock, these disturbances were greater than at Penang, and it is a fact to be noted, that at the former place, very heavy rain immediately followed the convulsion.

[1] *Pulau Nias, translated as Nias Island.*
[2] *Gunungsitoli, presently the largest town and nearby topographic high point on Nias.*

Note: Available at http://books.google.com/books?id=L0wyAQAAMAAJ&pg=PA604 or https://archive.org/details/journalofasiatic142asia

1843 Historical Account #2

Franz Junghuhn (1845), Chronologisch overzigt der aardbevingen en uitbarstingen van vulkanen in Neêrland's Indië (in vergelijkende zamenstelling met elkander), *Tijdschrift voor Neêrland's Indië [Tijdschrift voor Nederlandsch Indië]*, 7 (1), 30–68.
[Franz Junghuhn (1845), Chronology of earthquakes and volcanic eruptions in the Dutch East Indies (in comparison with one another), *Magazine for the Dutch East Indies*, 7 (1), 30–68.]

p. 58:

A. Aardbevingen.

No.	Verschijnselen.	Land en Provincie.	Dag.	Maand.	Jaar.
A. 47	Hevige aardbeving op De opgehevene zee stroomde over de Z. O. kust van *Nias* en verwoestte het dorp *Mego* tot aan den berg Sitolie. Ook bij *Baros* stroomde eene groote golf der zee over het land, doch keerde even plotselijk terug. (Jav. Cour.)	*Nias* en het tegenoverliggend gedeelte der Z. Westkust van *Sumatra* (bij *Tapanoelie*, *Baros*, *Singkel*)	Nacht 5–6	Jan.	1843

Translation from Dutch:

A. Earthquakes.

No.	Phenomena.	Country and Province.	Day.	Month.	Year.
A. 47	Severe earthquake. The raised sea flowed over the southeast coast of Nias and devastated the village Mego to Mount Sitolie[1]. Also at Baros flowed a great wave of the sea on the land, but returned as suddenly back. (Jav. Cour.)	Nias and the opposite part of the southwest coast of Sumatra (at Tapanuli[2], Baros[3], Singkel[4])	Night 5–6	Jan.	1843

[1] *Gunungsitoli, presently the largest town and nearby topographic high point on Nias.*
[2] *Cribb [2010] locates the 1877 Tapanuli administrative division as stretching from present-day Singkil to just north of the Equator. Alternatively, Tapanuli may have referred to present-day Central Tapanuli (Tapanuli Tengah) or specifically to the area around the Bay of Sibolga (formerly known by the Dutch* Baai van Tapanoeli*).*
[3] *Cribb [2010] locates 1877 Baros as several kilometers north of present-day Sibolga.*
[4] *Cribb [2010] locates 1877 Singkel in roughly the same location as present-day Aceh Singkil.*

Note: Available at http://books.google.com/books?id=FRMwAAAAYAAJ&pg=PA30

1843 Historical Account #3

Arthur Wichmann (1918), Die Erdbeben des Indischen Archipels bis zum Jahre 1857, *Verhandelingen der Koninklijke Akademie van Wetenschappen te Amsterdam*, Tweede Sectie, deel 20, no. 4, 193 pp., Johannes Müller, Amsterdam.
[Arthur Wichmann (1918), The earthquakes of the Indian archipelago until 1857, *Memoirs of the Royal Academy of Sciences of Amsterdam*, Second Section, part 20, no. 4, 193 pp., Johannes Müller, Amsterdam.]

pp. 111–112:

1843, Januar 5, 11½^h p. m. Barus [Baros], Abtlg. Sibolga, Residentsch. Tapanuli. Heftiges Erdbeben, wobei im Erdreich zahlreiche Risse sich bildeten.

Gegen Mitternacht fühlte man auf der Insel Nias, unweit der Westküste von Sumatra, Stösse, die aus dem Westen zu kommen schienen, dann aber in einer nördlichen Richtung sich fortsetzten. Sie waren anfangs nur schwach, nahmen allmählich an Heftigkeit zu und liessen alsdann keine bestimmte Stossrichtung mehr erkennen. Ihre Dauer betrug 9 Minuten. Ein Teil des Berges Horifa stürzte in den Abgrund, auch versank ein Teil der Brustwehr des Forts zu Gunungsitoli. Mit Ausnahme der Kaserne, sowie der Wohnung des Kommandanten, stürzten sämtliche Häuser ein. Nach Ablauf von 9 Minuten wälzte sich eine „himmelhohe" Flutwelle, aus SO kommend, gegen den NO-Strand und schwemmte den eine Stunde südlich von Gunungsitoli liegenden Kampong Mego hinweg. Zu gleicher Zeit erfolgten von zwei zu zwei Minuten Stösse. Die Fluterscheinungen währten bis Januar 6, 4½^h a. m., worauf ein noch heftigeres Erdbeben eintrat. Von den etwa 6 Minuten währenden Stössen kamen manche „aus W und wanderten gen N, doch änderten sofort ihre Richtung in S–N." Noch viele Tage später waren die Erschütterungen, obwohl in schwächerem Grade, wahrzunehmen. [1])

In dem obenerwähnten Barus war eine Flutwelle um 12½^h a. m. gegen die Küste angestürmt und hatte u.a. 3 Prauen 1922 Fuss (603 m) weit landeinwärts geschleudert. Stösse wurden noch um 4½^h, 6^h, 9^h a. m. sowie um 2^h und 11¾^h p. m. wahrgenommen. [2])

1843, Januar 5, Mitternacht. Pulu Pinang [Penang]. Ziemlich starker Stoss.

1843, Januar 6, 12^h 30 a. m. Singapore. Stoss. Dauer 8–10 Sekunden. O–W. [3])

[1]) D. F. S . Javasche Courant. Batavia 1843, 5 April, N^o. 27. — F. JUNGHUHN. Nieuwe gebeurtenissen in de natuur van Nederlandsch-Indië. Indisch Magazijn **1**. 4–6 Batavia 1844, p. 91–94. — W. F. VERSTEEG. Berigten over aardbevingen en berguitbarstingen . . . 1841–50. Natuurk. Tijdschr. Ned. Indië **18**. 1859, p. 289–290.

A. PERREY hatte auf Grund einer Angabe von TH. PLIENINGER mitgeteilt, dass auch in der Nacht 5/6. Juli auf Nias ein Erdbeben stattgefunden habe, mit Recht aber dazu bemerkt, dass hier augenscheinlich eine Verwechslung mit dem 5/6. Januar vorläge (Documents sur les tremblements de terre . . dans l'île de Sumatra. Nouv. Annales des Voyages. Paris 1861. **3**, p. 311).

[2]) F. VON KETWICH. Iets over de aardbevingen waargenomen ter Sumatra's Westkust. Natuur- en Geneesk. Archief **1**. Batavia 1844, p. 338.

[3]) DE CASTELNAU. Tremblement de terre à Singapore. Compt. rend. Acad. des Sc. **52**. Paris 1861, p. 881–882. — Die Angabe von R. BAIRD-SMITH (On Indian Earthquakes in 1843. Asiatic Journ. N. S. **12**. 2. London 1844, p. 604) und von E. KLUGE (Synchronismus und Antagonismus der Erdbeben. Leipzig 1863, p. 44), dass das Beben am 4. Januar gegen Mitternacht stattgefunden habe, beruht auf einem Irrtum.

Translation from German (and, in places, Dutch and French):

1843, January 5, 11:30 p.m. Barus [Baros], Sibolga Division, Tapanuli Residency. Violent earthquake, with numerous cracks formed in the soil.

Around midnight on the island of Nias, near the west coast of Sumatra, we felt shocks that seemed to come from the west, but then continued in a northerly direction. They were initially weak, gradually increased in intensity and then the direction of the shocks could no longer be recognized. Its duration was 9 minutes. A part of Mount Horifa fell into the abyss, and a part of the parapet of the fort to Gunungsitoli also sank. With the exception of the barracks, as well as the home of the commander, all the houses collapsed. After the expiration of 9 minutes, a "sky high" tidal wave coming from the southeast, rolled towards the northeast and flooded the beach one hour south of Gunungsitoli lying across Kampong Mego. During this time, shocks occurred every two minutes. The flood phenomena lasted until January 6, 4:30 a.m., and was followed by a still more violent earthquake. Of these shocks, which lasted about 6 minutes, some came "from the west and migrated north, but immediately changed their direction to south–north." Many days later the shocks, although to a lesser degree, were still perceived. [1])

In the above-mentioned Barus a tidal wave assailed against the shore until 12:30 and, among others, flung 3 praus [Indonesian sailboats] 1,922 feet (603 m) inland. Shocks were still perceived around 4:30, 6:00, 9:00 a.m. and at 2:00 and 11:45 p.m. [2])

1843 January 5, midnight. Pulu Pinang [Penang]. Fairly strong shock.

1843 January 6, 12:30 a.m. Singapore. Shock. Duration 8–10 seconds. East–west. [3])

[1]) D. F. S . Javasche Courant. Batavia 1843, 5 April, N°. 27. — F. JUNGHUHN. New events in the nature of the Dutch East Indies. Indisch Magazijn **1**. 4–6 Batavia 1844, p. 91–94. — W. F. VERSTEEG. Posts about earthquakes and mountain eruptions . . . 1841–50. Natuurk. Tijdschr. Ned. Indië **18**. 1859, p. 289–290.

A. PERREY was informed by TH. PLIENINGER that at night on 5/6 July, an earthquake took place in Nias, but rightly remarks that this is an apparent confusion with the 5/6 January original (Documents on earthquakes ... in the island of Sumatra. Nouv. Annales des Voyages. Paris 1861. **3**, p. 311).

[2]) F. VON KETWICH. On the earthquakes observed on Sumatra's west coast. Natuur- en Geneesk. Archief **1**. Batavia 1844, p. 338.

[3]) DE CASTELNAU. Earthquake in Singapore. Compt. rend. Acad. des Sc. **52**. Paris 1861, p. 881–882. — The indication of R. BAIRD-SMITH (On Indian Earthquakes in 1843. Asiatic Journ. N. S. **12**. 2. London 1844, p. 604) and of E. KLUGE (Synchronism and antagonism of the earthquake. Leipzig 1863, p. 44), that the quake had occurred on January 4, around midnight, is based on an error.

Note: The original version in German is available at http://www.dwc.knaw.nl/toegangen/digital-library-knaw/?pagetype=publDetail&pId=PU00011872

1861 Historical Account #1

***The Singapore Free Press*, 11 April 1861 (Thursday morning).**

p. 3, column 2:

Further accounts are given of the earthquake of 16th February on Sumatra. At Siak[1] some shocks were felt at 10 minutes past seven in the evening, lasting about three minutes, the direction being from North to South. The damage done on the west Coast of Sumatra by the earthquake, and especially by the rising of the sea, was very great. At Singkel[2] only two houses remained and 17 natives were drowned. The military post at Lagundie[3], on the island of Nias, was completely destroyed. The sea came so suddenly on the garrison that they fled, half clothed, to the campong Hilibobo. Twelve of the soldiers and 32 natives were drowned. The rest of the garrison afterwards proceeded to Gunong Sitoli where they arrived in a very sick and wretched condition.

At Natal[4] great damage was done by the earth- and seaquake. The inhabitants took refuge on the neighboring hills.

[1] *Cribb [2010] locates the 1877 Siak administrative division as covering the region inland from Tapanuli all the way to the Strait of Malacca. The town of Siak is nearer the Strait of Malacca, northeast of present-day Pekanbaru.*
[2] *Cribb [2010] locates 1877 Singkel in roughly the same location as present-day Aceh Singkil.*
[3] *Lagundri or Lagundi, on southwestern Nias.*
[4] *Cribb [2010] locates 1877 Natal along the west coast of present-day North Sumatra province, ~140 km south of Sibolga.*

1861 Historical Account #2

***The Singapore Free Press*, 25 April 1861 (Thursday morning).**

p. 3, columns 1–3:

The *Java Courant* furnishes detailed accounts of the earthquakes &c. which took place in the Government of the West Coast of Sumatra, in the months of February and March last, some extracts from which we subjoin:—

On the 16th February a very heavy and unusually prolonged shock of earthquake was experienced throughout the whole of the territories comprised in this Government. In the northern part of the country the earthquake was accompanied by a sea quake.

At Padang, in the surrounding districts, and in the southern division, the shocks were felt about ½ past 7 o'clock in the evening. They were heavy and continuous and lasted about two minutes. The motion was horizontal and undulating; the direction at Padang was from north to south. At Pau (in the neighborhood of Padang) the direction was observed to be shifting.

At Priaman[1] the motion was felt at 10 minutes past seven; it seemed to have been heavier there than at Padang, and was said to have lasted between four and five minutes.

In the Padang Highlands the earthquake was noticed before seven o'clock. The motion was so heavy that people had difficulty in keeping on their feet; it was horizontal, undulating, and the direction from the South East to the North West. The shocks were estimated to have lasted about five minutes, but the heaviest one only a minute and a half. The tremulous motion was repeatedly observed till late in the night and also on the following days. It was observed that the volcano Merapi[2] had lately thrown out more smoke than usual.

At Ayarbangis[3] the first shocks were felt about a quarter to 7. They were preceded by a subterranean noise which was also heard during the shocks. The first two shocks were vertical, the rest horizontal. The motion was very heavy and lasted a minute and a half. The shocks were repeated in the evening of the 16th at 9 and 12 and on the 17th at 1 ¾, 3 ½ [?][4] and 6 A. M. The motion was said to be in the direction of East South East to West North West.

At Ayarbangis, during the occurrence of the earthquake, there was great agitation of the sea. The river at one time would be left dry, and then the sea would return with a tremendous rush. During the whole forenoon of the 17th there was a regular ebbing and flowing in the river; sometimes in the course of a quarter of an hour.

Thousands of dead fishes were floating round the island Panjang which lies off Ayarbangis.

The effects of the earth and sea quakes at the Batu islands were frightful. On Pulo Telo[5], on which the government establishment is situated, the earthquake commenced at 7 in the evening; it lasted about five minutes, and was followed by lighter shocks throughout the whole evening. About an hour after the first shock, the sea rushed in, so that soon all the kampongs were under water. On the night of the 16th the tide ebbed and flowed four times at this island. Much damage was done by the sea. The other islands of the group also suffered severely, especially Simo[6], where eighty houses were destroyed.

At Talu, in the Ophir districts[7], the first shock occurred about seven in the evening. The motion was very heavy and was preceded by a soft rumbling noise. In the night of the 16th three shocks were felt at Rau[8] about half past seven p. m. lasting about two minutes.

At Natal[9] the motion of the earthquake began about half past seven in the evening. It was very heavy and lasted about four minutes. The river overflowed its banks and in the campong Alyeh the water stood about 1½ yards deep.

In the division Mandheling[10] and Ankola[11] in the interior, the earthquake was very heavy and did much damage. A great number of houses were thrown down; sawahs were, as it seemed, turned over, and earthslips took place, one of which buried the campong Si Along under it. At Penyabungan[12], the chief place of Mandheling, the shocks commenced about half past six, and from that period until 8 o'clock on the morning of the 17th, not less than 25 shocks were observed. It was thought at Penyabungan that the shocks proceeded from the direction of the volcano Merapi[13], which is situated in Mandheling, S. S. Westwards from Penyabungan, but in other parts of the district it was observed that the motion was from North West to South East.

At Siboga[14] the earthquake began at seven p. m. The first shocks lasted four minutes, at one time they were jerking, at another softly undulating. There is much uncertainty as the direction. According to some persons they were from West South West to East North East, while others thought they were directly the reverse. A noise was heard like that produced by a ball rolling over a skittle ground. In different places the ground was rent open. Soon after the first shock the water in the bay of Tapanoli[15] was greatly agitated, and twice it retired so far back that the vessels anchored in the harbour took the ground, but immediately afterwards it rushed in, overflowing the bazar and the high road which runs along the shore.

At Baros[16] the earthquake began about 7 lasting about four minutes, but there were repeated shocks in the course of the night. The sea also inundated the shore to the depth of 2 or 3 feet. The direction was supposed to be from East to West.

At Singkel[17] some light shocks were first felt. At half past 6 p. m. the heavy shocks commenced which were very prolonged. At the first shock the ground split open in many places, and most of the buildings, including the barracks, were rendered uninhabitable. While preparations were being made for the shelter of the troops for the night, the sea rose and soon the whole of Singkel was under water. On the 25th February the bazar could still be passed through in a boat. Twenty persons were drowned. According to trustworthy information the earthquake of the 16th February reached northwards to Acheen[18], and in some of the pepper ports, great damage, attended with loss of life, was experienced, and much injury was also caused in the Batta lands[19].

The earthquake of the 16th February appears to have been more felt in the island of Nias than in other places.

Beginning on the south coast mention must first be made of the establishment at Lagundi. Previous to the 16th some light shocks were felt there. On the evening of the 16th about ½ past 6, the first heavy shocks were observed. These lasted about three minutes and were so severe, that some soldiers of the garrison were thrown down. Three less heavy shocks soon succeeded. The direction was from North West to South East. At a quarter to seven the sea set in from the South East and by half past seven most of the buildings were destroyed. The water must have risen very high, some accounts say seven yards. The gun boat lying in the roads was torn from her anchors and thrown high upon the shore. Fifty persons perished. At Gunong Sitoli[20] on the North East Coast of Nias the earthquake began about half past 6 p. m. It was so very strong that many persons were thrown down. The direction was from South East to North west. The sea retired about 32 yards and then rushed in with great violence, damaging many campongs on the shore. A schooner laden with paddy was cast ashore.

Distinct shocks were felt on board the screw corvette *Princess Amelia* and two merchant vessels which were in different positions off the coast.

From the 16th February to the 9th March repeated shocks were observed at Padang, and in the Padang Highlands, as well as further to the North.

On the 9th March a heavy shock was felt at Padang. This was also felt at Ayarbangis and in the Batu islands, in which last it was said to be much more severe than that experienced on the 16th February. It was also accompanied by a rising of the sea, which produced much damage. A great many of the inhabitants were drowned and the campongs swept away.

The shocks were much heavier in the north of Sumatra than in the southern parts, while it was observed that in some of the islands the north west and west coasts suffered much more damage than the other parts of the shores.

[1] *Pariaman, along the west coast of present-day West Sumatra, ~40 km north of Padang.*
[2] *The first occurrence of "Merapi" in this article appears to refer to Mount Marapi, just east of Mount Singgalang in present-day West Sumatra. See also note 13.*
[3] *Air Bangis, along the west coast of present-day West Sumatra, just north of the Equator.*
[4] *This fraction is barely legible in the available copy.*
[5] *Pulau Telo, translated as Telo Island.*
[6] *Likely Simuk Island, just west of Telo Island.*
[7] *Talu and the present-day Ophir postal area are in northern West Sumatra, east of Air Bangis.*
[8] *Cribb [2010] locates 1877 Rau near Air Bangis.*
[9] *Cribb [2010] locates 1877 Natal along the west coast of present-day North Sumatra province, ~140 km south of Sibolga and ~40 km northwest of Air Bangis.*
[10] *Cribb [2010] locates 1877 Mandaheling (also Mandailing) in present-day North Sumatra province, inland from Natal.*
[11] *Cribb [2010] locates 1877 Angkola in present-day North Sumatra province, inland from Natal and southeast of Mandailing.*
[12] *Panyabungan, in present-day Mandailing Natal regency in southern North Sumatra province.*
[13] *At the second occurrence of "Merapi" in this article, it is described as being "in Mandheling, [south-southwest of] Penyabungan." This location matches that of Mount Sorikmarapi in present-day North Sumatra. See also note 2.*
[14] *Sibolga, on the west coast of present-day North Sumatra province.*
[15] *The Bay of Sibolga, formerly known by the Dutch* Baai van Tapanoeli.
[16] *Cribb [2010] locates 1877 Baros as several kilometers north of present-day Sibolga.*
[17] *Cribb [2010] locates 1877 Singkel in roughly the same location as present-day Aceh Singkil.*
[18] *The boundaries of Aceh (also Atjeh or Achin) have moved repeatedly in the past two centuries. Singkel did not join Aceh until 1903 [Cribb, 2010].*
[19] *This may refer to the inland areas of North Sumatra inhabited by Bataks, as Junghuhn [1847] had used the term "Die Battaländer auf Sumatra" ("The Batta lands in Sumatra") to refer to such places. The exact locations are unclear.*
[20] *Gunungsitoli, presently the largest town and nearby topographic high point on Nias.*

1861 Historical Account #3

Frédéric Zurcher and Élie Margollé (1866), *Volcans et Tremblements de Terre*, 372 pp., Hachette et Cie, Paris. Republished by Adamant Media Corporation, 2006.

pp. 282–286:

Un de nos compatriotes, établi au port de Padang, a donné la description suivante du tremblement de terre qui eut lieu, en 1861, dans la partie méridionale de l'île volcanique de Sumatra:

« Le tremblement de terre commença par une commotion qui se fit sentir le 16 février, à sept heures du soir, et qui dura environ cent quinze secondes. Grâce à la construction particulière de nos maisons, le mal s'est borné à peu de chose, bien que l'extrême violence des trépidations du sol nous fît appréhender qu'aucune d'elles ne pût résister. Tous les habitants s'enfuyaient en criant. Quant à moi, je me croyais sur le pont d'un navire battu par la tempête, et j'éprouvais tous les symptômes du mal de mer.

« L'établissement de Singkel, sur l'extrême frontière des possessions hollandaises, du côté du royaume d'Achem, a disparu sous les eaux, par suite de l'affaissement de la presqu'île sur laquelle il était construit; la mer couvre aujourd'hui l'emplacement où s'élevaient le fort et les magasins du gouvernement. La garnison a été sauvée.

« À Polo Nyas, la mer, refoulée sur ses rivages par une violente commotion sous-marine, a complètement rasé le fort, ainsi que l'établissement de Lagondie, et emporté, en se retirant, quarante-neuf soldats et indigènes malais. Les secousses étaient si fortes que les hommes les plus robustes étaient violemment renversés sur le sol.

« Du côté de Gunung-Sitalie, des villages entiers ne sont plus qu'un monceau de ruines; un grand nombre d'indigènes ont été ensevelis sous les décombres.

« Sur la côte occidentale de la même île, le sol s'est affaissé sur divers points et soulevé sur d'autres; des îlots de corail ont surgi du sein des eaux; d'autres, au contraire, ont disparu. Des centaines d'indigènes ont trouvé la mort au milieu de ces bouleversements subits.

« À Baros et à Siboga la terre s'est entr'ouverte, et des sources d'eau bouillante ont jailli en divers endroits. Des témoins oculaires rapportent que çà et là le sol s'ouvrait et se refermait alternativement, comme si la terre se fût tordue sous l'effort du travail volcanique qui s'accomplissait en son sein.

« Toute la côte d'Achem a été ravagée par l'invasion subite de la mer, qui, pénétrant dans l'intérieur des terres, a renversé maisons, arbres, récoltes, et emporté en se retirant un grand nombre d'habitants.

« Aux îles Batoa, la mer, soulevée par une force irrésistible à une grande hauteur, s'est élancée en bouillonnant dans l'intérieur des terres, anéantissant tout ce qui se trouvait sur son passage; puis, se retirant avec la même rapidité, elle a enlevé sept cents indigènes sur une seule île, ne laissant derrière elle qu'un sol affreusement raviné où l'œil cherche en vain un vestige de la luxuriante végétation qui la couvrait quelques heures auparavant.

« La terre n'a pas, pour ainsi dire, cessé de trembler depuis la soirée du 16 février; nous avons pu constater chaque jour un plus ou moins grand nombre de secousses. Le Mérapi[1], dont le cratère n'avait pas donné signe de vie depuis cinq ans, vomit en ce moment d'épaisses colonnes de fumée; le Talang et le Singaland[2] font entendre de sourdes détonations... »

[1] In the 2nd edition (1868), this was corrected to Merapi. Presumably this refers to Mount Marapi, just east of Mount Singgalang in West Sumatra, instead of Mount Merapi on Java.
[2] In the 2nd edition (1868), this was corrected to Singalang.

Note: See Zurcher and Margollé [1868] for English translation.
Note: 2nd edition (1868) available at http://books.google.com/books?id=iQcKAAAAIAAJ&pg=PP9 and https://archive.org/details/volcansettrembl01marggoog

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1861 Historical Account #4

Frédéric Zurcher and Élie Margollé (1868), *Volcanoes and Earthquakes*, translated by W. Lockyer, 261 pp. and 15 plates, Richard Bentley, London. Republished by Cambridge University Press, New York, 2012.

pp. 193–195:

A Frenchman established at the port of Padang has given the following description of the earthquake which took place in 1861, in the southern part of the volcanic isle of Sumatra:

'The earthquake began by a commotion which was felt on February 16, at seven in the evening, and which lasted about 115 seconds. Thanks to the peculiar construction of our houses the evil was limited, although the extreme violence of the motion of the ground made us think that some of them would not hold out. All the inhabitants fled with cries. I felt as if I were on the bridge of a vessel beaten by a tempest, and experienced all the symptoms of sea-sickness.

'The establishment of Singkel[1], on the extreme frontier of the Dutch possessions near the kingdom of Acheen[2], disappeared under the water, in consequence of the sinking of the peninsula on which it was built. The sea now covers the place on which were the fort and government magazines. The garrison was saved.

'At Polo Nyas[3], the sea, dashed on the shore by a violent submarine commotion, completely razed the fort as well as the establishment of Lagondie[4], and carried away forty-nine soldiers and Malay inhabitants when it retreated. The shocks were so strong that the most robust men were violently thrown on the ground.

'On the side of Gunung-Sitalie[5] entire villages were soon nothing more than a heap of ruins, and a great number of the inhabitants were buried under the *débris*.

'On the western coast of the same island the ground sank in many places, and rose in others; coral islands rose from the bosom of the waters, others, on the other hand, disappeared. Hundreds of inhabitants died in the midst of these sudden convulsions.

'At Baros[6] and Siboga[7] the earth opened, springs of boiling water spouting out in different places. Eye-witnesses relate that here and there the ground opened and closed alternately, as if the earth were bent under the effort of volcanic work which was going on in its depths.

'The coast of Acheen was ravaged by the sudden invasion of the sea, which, penetrating into the interior of the land, overturned houses, trees, and harvests, and in receding carried away a great number of inhabitants.

'In the Batoa isles[8] the sea, upheaved by an irresistible force to a great height, penetrated into the interior of the country, annihilating all that it met with in its passage; then, retiring with the same rapidity, it carried off 700 inhabitants from a single island, leaving nothing behind it but a frightfully ravined surface, where the eye looked in vain for a vestige of the rich vegetation which covered it a few hours before.

'The earth has not, so to speak, ceased to tremble since the evening of February 16; we have each day observed a greater or less number of shocks. The Merapi[9], the crater of which has not given signs of life for five years, emitted at this time thick columns of smoke; and from the Talang and Singaland[10] came dull detonations.'

[1] *Cribb [2010] locates 1877 Singkel in roughly the same location as present-day Aceh Singkil.*
[2] *The boundaries of Aceh (also Atjeh or Achin) have moved repeatedly in the past two centuries. Singkel did not join Aceh until 1903 [Cribb, 2010].*
[3] *Pulau Nias, translated as Nias Island.*
[4] *Lagundri or Lagundi, on southwestern Nias.*
[5] *Gunungsitoli, presently the largest town and nearby topographic high point on Nias.*
[6] *Cribb [2010] locates 1877 Baros as several kilometers north of present-day Sibolga.*
[7] *Sibolga, on the west coast of present-day North Sumatra province.*
[8] *The Batu Islands, south of Nias.*
[9] *Presumably this refers to Mount Marapi, just east of Mount Singgalang in West Sumatra, instead of Mount Merapi on Java.*
[10] *Mount Singgalang, a volcano in West Sumatra, just west of Mount Marapi.*

Note: See Zurcher and Margollé [1866] for original version in French.
Note: Available at https://archive.org/details/volcanoesearthqu00zurcrich

1861 Historical Account #5

Arthur Wichmann (1922), Die Erdbeben des Indischen Archipels von 1858 bis 1877, *Verhandelingen der Koninklijke Akademie van Wetenschappen te Amsterdam*, Tweede Sectie, deel 22, no. 5, 209 pp., Koninklijke Akademie van Wetenschappen, Amsterdam.
[Arthur Wichmann (1922), The earthquakes of the Indian archipelago from 1858 to 1877, *Memoirs of the Royal Academy of Sciences of Amsterdam*, Second Section, part 22, no. 5, 209 pp., Royal Academy of Sciences, Amsterdam.]

pp. 22–27:

1861, Februar 16, abends. Das ausgedehnteste Beben, das wohl jemals Sumatra berührt hat und das noch weiter auf der Malaiischen Halbinsel und in ganz geringem Masse auch auf Java gefühlt worden war. Am stärksten gelangte es an der westlichen Seite von Sumatra, sowie auf den vorliegenden Inseln zur Äusserung.

Gegen 7^h p. m. Bengkulen. Die Stösse währten reichlich eine Minute. SO–NW. [1])

Gegen $7½^h$ p. m. Padang. Residentsch. Padangsche Benedenlanden. Die Stösse waren in der Stadt und deren Umgebung, sowie im südlichen Teile der Residentschaft, sehr heftig und dauerten etwa 2 Minuten. Die Richtung der horizontalen und wellenförmigen Stösse war in Padang eine nordsüdliche. In Pauh unweit Padang meinte man einen Wechsel der Richtung bemerkt zu haben.

7^h 10^m p. m. Priaman, Abtlg. Priaman, wo die Stösse stärker waren, als in Padang und auch länger währten (4–5 Minuten).

Gegen 7^h p. m. Residentschaft Padangsche Bovenlanden. Die starken, horizontalen und wellenförmigen Stösse waren äusserst heftig und währten etwa 5 Minuten. Richtung SO–NW. Sie wiederholten sich bis spät in die Nacht hinein und machten sich auch noch an den folgenden Tagen bemerkbar. Der Gunung Merapi rauchte stärker als dies sonst der Fall war. [2])

1861, Februar 16, $6¾^h$ p. m. Ajer Bangis, Distr. und Abtlg. Ajer Bangis, Resid. Padangsche Benedenlanden. Sehr heftige Stösse, denen ein unterirdisches Getöse vorhergegangen war und das die Stösse auch begleitet hatte. Die ersten beiden waren vertikal, die folgenden dagegen horizontal. Dauer etwa 1½ Minuten. Richtung O SO–W NW oder umgekehrt. Die Stösse stellten sich aufs neue um 9^h und dann wieder um 12 Uhr des Nachts ein.

Während des Bebens wurde die Flussmündung beinahe trocken gelegt, worauf eine Flutwelle mit grosser Gewalt gegen die Küste anstürmte. In der Umgebung des vor Ajer Bangis liegenden Pulu (Eiland) Pandjang trieben Tausende von toten Fischen auf dem Meere umber.

7^h p. m. Talu, Ophirdistrikte, Abtlg. Lubuksikaping, Resid. Padangsche Benedenlanden. Sehr heftige Stösse, denen ein unterirdisches Getöse vorherging. Während der Nacht folgten noch 3 Stösse.

$7½^h$ p. m. Rau, Distr. Lubuksikaping und Rau, Abtlg. Lubuksikaping. Die Stösse dauerten etwa zwei Minuten. [3])

7½^{h} p. m. Natal, Distr. und Abtlg. Natal, Resid. Tapanuli. Sehr heftiges Beben, das etwa 4 Minuten währte. Der Fluss trat aus seinen Ufern, so dass das Wasser im Kampung Atjèh etwa 1½ m hoch stand.

6¾^{h} p. m. Panjabungan (Penjabungan), U. Abtlg. Gross-Mandailing und Batang-Natal, Abtlg. Mandailing und Angkola, Resid. Tapanuli. Heftiges Beben. Bis zum 17, 8^{h} a. m. wurden 25 Stösse gezählt. Richtung NW–SO. Der in der ganzen Abteilung angerichtete Schaden war sehr gross. Zahlreiche Häuser stürzten ein, Reisfelder waren gleichsam umgepflügt worden und eine Folge der Erdschlipfe war, dass man den Kampung Sialang verlegen musste.

7^{h} p. m. Sibolga (Siboga), Distr. und Abtlg. Sibolga, Resid. Tapanuli. Heftige Stösse, die in eine wellenförmige Bewegung übergingen. Dauer 4 Minuten. Richtung W SW–O NO oder umgekehrt. [4]) Das Beben war von einem rollenden Getöse begleitet und an verschiedenen Stellen bildeten sich Spalten im Boden. Kurz nach dem ersten Stösse drang eine Flutwelle in die Bucht von Tapanuli, um sich noch zweimal soweit zurückzuziehen, dass die auf der Reede ankernden Schiffe auf Grund gerieten. [5])

1861, Februar 16. 7^{h} p. m. Barus, Distr. Barus, Abtlg. Sibolga, Residentsch. Tapanuli. Dauer der Stösse 4 Minuten. Sie wiederholten sich noch häufig im Laufe der Nacht. Richtung anscheinend O–W. Die hereinbrechende Flutwelle stieg nicht höher als 2–3 Fuss.

6½^{h} p. m. Singkel, Unterabtlg. Singkel, [6]) Abtlg. Westküste von Atjèh, Gouvernt. Atjèh. Heftige Erschütterungen, nachdem einige schwache Stösse vorhergegangen waren. Dauer 10 Minuten. Gleich nach den ersten Stössen begannen sich NW–SO gerichtete Spalten zu bilden, wodurch die meisten Gebäude, darunter die Kasernen, unbewohnbar wurden. Gleichzeitig brach eine Flutwelle herein und überschwemmte den ganzen Ort. Nachdem sie sich zurückgezogen, kehrte sie noch einige Male zurück, doch blieb der Ort unter Wasser, so dass man am 25. Februar noch in einem Ruderboot über den Marktplatz fahren konnte. Uebrigens hatte sich bei Gelegenheit dieses Bebens eine alte verschüttete Flussmündung wieder geöffnet und war südlich vom Hauptmündungsarm eine neue Flussrinne entstanden. [7])

In den damals anabhängigen Batakländern soll das Beben sich ebenfalls in heftiger Weise geäussert haben. Einige Einzelheiten hat A. SCHREIBER später mitgeteilt. [8]) In der Nähe von Baringin, an der Quelle des Aek Mandurana, wurde die Solfatare zu einem lebhaft tätigen Sprudel umgestaltet. [9])

Ohne Zeitangabe. Atjèh. Heftiges Erdbeben, begleitet von Flutwellen, die in den verschiedenen Häfen vielen Schaden anrichteten.

Ein Teil der Küste von Susoh, Unterabtlg. Tapat Tuan, Abtlg. Westküste von Atjèh erlitt mannigfache Veränderungen, u. a. wurde die vorspringende Landzunge bei Udjung Seranggan von den Wellen verschlungen, so dass ihre frühere Lage nur noch an den aus dem Wasser emporragenden Stämmen der Kokospalmen zu erkennen war. [10])

1861, Februar 16, gegen 6½^{h} p. m. Insel Nias. Zu Lagundi im südlichen Teile der Insel der erste heftige Stoss, nachdem bereits Tage vorher einige schwache Stösse bemerkt worden waren. Dauer etwa 3 Minuten. Kurz darauf folgten 3 weniger heftige Stösse in NW–SO. Um 6¾^{h} wälzte eine gewaltige Flutwelle sich gegen die Südostküste und erreichte dort eine Höhe von etwa 7 m. Um 8½^{h} waren die meisten Gebäude bereits weggespült, wobei 50 Menschen ums Leben kamen.

In dem an der NO-Küste liegenden Hauptort Gunungsitoli begann um 6¾^h das Beben ebenfalls mit grosser Heftigkeit. Richtung SO–NW oder umgekehrt. Das Meer wich um 32 m zurück, worauf es bei der Wiederkehr mit grosser Gewalt gegen die Küste anstürmte und dabei mehrere Stranddörfer vernichtete. Auch wurden Schiffe auf den Strand geschleudert. An der Westküste sollen mehrere Klippen zum Vorschein gekommen und das kleine Eiland Lapau [11]) an der Nordseite fast gänzlich mit Nias verbunden worden sein.

Ebenfalls stark in Mitleidenschaft wurden die Batu-Inseln gezogen. Auf Pulu Tello begannen die Stösse um 7^h p. m. und währten 5 Minuten, aber schwächere wurden noch im Laufe der ganzen Nacht wiederholt beobachtet. Eine Stunde nach Ablauf des ersten Stosses wälzte sich eine Flutwelle gegen den Strand und setzte sämtliche dort liegender Ortschaften unter Wasser. Man konnte während der Nacht vom 16.–17. eine viermalige Ebbe und Flut feststellen. [12]) Auch andere Inseln dieser Gruppe hatten schwer zu leiden gehabt und zwar besonders das unter 0°5' S, 97°52' O liegende Pulu Simuk (Simo), irrigerweise auch als Pulu Kalapa bezeichnet, [13]) an der sich die Flutwelle bereits vor Beginn der Stösse gezeigt hatte. Am ärgsten hatte sie zwischen Simuk (Simo), Babanirege und Lakao [14]) hausgehalten. Von den 120 Häusern wurden 96 zerstört und von der 1045 Seelen zählenden Bevölkerung büssten 675, überdies 103 Fremdlinge, ihr Leben ein. Allein vom Kampung Babanirege wurden von den 282 Bewohnern 205 auf der Flucht von der Welle weggeschwemmt. [15])

Felsblöcke wurden von der Woge 100 und selbst 200 Schritte weit landeinwärts geschleudert. [16])

Ferner wurde auf dem offenen Meere an mehreren Stellen ein Seebeben beobachtet. Das amerikanische Schiff „Humboldt" empfand einen Stoss in der Höhe der Insel Simölu (Simalur), das ebenfalls unweit der Westküste von Sumatra aufragt; das niederländische Schiff „Vesta", Kapt. GERREBRANDS einen solchen in der Höhe der Pageh- (eigentlich Pagai-) Inseln unter 0°30' S, 97° O. [17]) Auf der niederländischen Korvette „Prinses Amalia", die auf der Fahrt von Singkel nach Atjèh begriffen war, beobachtete man Stösse und ein Erzittern des Schiffes. [18])

Während merkwürdigerweise von der Ostküste von Sumatra jegliche Nachricht fehlt, wurde auf der Malaiischen Halbinsel sowie in Singapore ein Stoss gefühlt [19]) und aus dem letzterwähnten Orte wurde des Näheren berichtet, dass um 7^h 34^m p. m. ein wellenförmiges Beben aufgetreten war, das etwa 2 Minuten dauerte. Richtung SW–NO. [20])

7½^h p. m. Penang (Pulu Pinang). Heftiges wellenförmiges Beben, bei dem zugleich 3 Stösse unterschieden werden konnten. Richtung N–S. Etwa 5 Minuten vor Eintritt des Bebens wurde eine aussergewöhnliche Bewegung des Meeres bemerkt. [21])

7^h 35^m p. m. Japara, Distr. u. Abtlg. Japara, Resid. Samarang. Einige Stösse. Richtung S–N, z. Tl. aber SW–NO. [22])

[1]) M. TH. REICHE. Aanteekeningen omtrent aardbevingen en andere natuurverschijnselen. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 114.

[2]) M. TH. REICHE. Aanteekeningen omtrent aardbevingen en andere natuurverschijnselen. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 116.

[3]) M. TH. REICHE. Aanteekeningen omtrent aardbevingen en andere natuurverschijnselen. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 116–117.

[4]) J. J. DE WILDE. (Topographische schets von Sibogha. Geneesk. Tijdschr. Ned. Ind. *11*. Batavia 1864, p. 110) gibt als Richtung S/S.–N/O. an und sagt, dass am Schluss des Bebens auch vertikale Stösse aufgetreten seien.

[5]) M. TH. REICHE 1. c. pag. 118.

[6]) Damals noch zur Residentsch. Tapanuli gehörend.

[7]) M. TH. REICHE. Aanteekeningen omtrent aardbevingen en andere natuurverschijnselen. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 118–119.

[8]) Die südlichen Batta-Länder auf Sumatra. Petermanns Mittlg. *12*. Gotha 1876, p. 68. Irrtümlicherweise wird das Beben in das Jahr 1862 verlegt.

[9]) Näher bekannt wurde diese heisse Schlammquelle, als sie am 17. Mai 1892, infolge eines Bebens, abermals in heftige Wallung geriet.

[10]) K. F. H. VAN LANGEN. Atjeh's Westkust. Tijdschr. K. Nederl. Aardr Genootsch. (2) *5*. M. U. A. 1888, p. 225.

[11]) Ein Eiland dieses Namens findet sich nicht auf den Karten von Nias. Das einzige, welches für den vorliegenden Fall in Betracht kommen könnte, wäre das unter 1°24½' N, 97°12',8 O liegende Ganëu, das in der Nähe des Strandes liegt und mit diesem durch ein Riff verbunden ist.

[12]) M. TH. REICHE. Aanteekeningen omtrent aardbevingen en andere natuurverschijnselen. Natuurk. Tijdschr. Ned. Indië *25*. Batavia 1863, p. 120.

[13]) Pulu Kalapa würde Kokos-Insel bedeuten, doch liegt in diesem Falle wohl eine Verstümmelung des auf den damaligen englischen Seekarten anzutreffenden Klapps Island vor.

[14]) L. HORNER nennt die erwähnten Ortschaften Limo (Druckfehler für Simo), Bawaniregeh und Laguo (Batoe-eilanden, ten W. van Sumatra gelegen. Tijdschr. voor Neêrl. Indië *3*. l. Batavia 1840, p. 341).

[15]) Nach L. HORNER besass die Insel Simuk Ende 1837 eine Bevölkerung von 513 Seelen, so dass sie bis 1861 eine Verdoppelung erfahren haben muss.

[16]) An Earthquake in the East at Simo. Nautic. Magazine. London 1861, p. 553, — ALEXIS PERREY. Note additionelle . . . . à un mémoire sur les tremblements de terre à Sumatra. Nouv. Ann. des Voyages (6) *7*. T. IV. Paris 1861, p. 42–43.

[17]) M. TH. REICHE l. c. pag. 121. — Mededeelingen uit de Journalen uitgegeven door het Kon. Meteorolog. Instituut. Utrecht 1867, p. 16, 2de druk 1896, p. 68.

[18]) Zakelijk Verslag van de Verrigtingen der Nederl. Marine in Oost-Indië, gedurende het jaar 1861. Verhandel. en berigten betr. het Zeewezen *24*. 2. Amsterdam 1864, p. 218.

[19]) H. N. R(IDLEY). Earthquake in the Malay Peninsula. Journ. Strait Branch R. Asiatic Soc. N°. *25*. 1894. Singapore, p. 169.

[20]) (F.) DE CASTELNAU. Tremblement de terre à Singapore le 16 février 1861. Compt. rend. Acad. des Sc. *52*. Paris 1861, p. 881–882.

[21]) J. M. GILLISS. Earthquake in the Island of Penang. Amer. Journ. of Sc. (2) *32*. New Haven 1861, p. 297.

[22]) M. TH. REICHE. Aanteekeningen omtrent aardbevingen en andere natuurverschijnselen. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 113.

Note: All footnotes for this source were copied verbatim from the original, except that they have been renumbered here to be sequential.

Translation from German (and, in places, Dutch and French):

1861, February 16, evening. The most extensive quake, which has probably ever touched Sumatra and was also felt on the Malay Peninsula and to a very small amount on Java. The hardest hit was the western side of Sumatra, as well as the islands. Here are their observations.

Around 7:00 p. m. Bengkulu. Many shocks lasting one minute. Southeast–northwest. [1])

Around 7:30 p. m. Padang. Padangsche Benedenlanden[a] Residency. The shocks were felt in town and the surroundings, as well as in the southern parts of the residency, very violent and lasted about 2 minutes. The direction of the horizontal and wavy shocks was north–south in Padang. In Pauh near Padang a change of direction was thought to have been noticed.

7:10 p. m. Pariaman, Pariaman Division, the shocks were stronger than in Padang and lasted longer (4–5 minutes).

Around 7:00 p. m. Padangsche Bovenlanden[b] Residency. The strong horizontal and wavy shocks were extremely violent and lasted about 5 minutes. Southeast–northwest direction. They repeated until late into the night and were noticeable even in the following days. Mount Merapi[c] was smoking more than has been the case otherwise. [2])

1861, February 16, 6:45 p. m. Air Bangis, Air Bangis District and Division, Padangsche Benedenlanden Residency. Very violent shocks, which were preceded by and accompanied by an underground noise. The first two shocks were vertical, the following, in contrast, horizontal. Duration approximately 1½ minutes. Direction east-southeast to west-northwest or vice versa. The shocks geared up again at 9:00 and then again at 12 o'clock at night.

During the earthquake, the estuary was placed almost dry, followed by a tidal wave that stormed with great force against the coast. Off the coast of Air Bangis, on Pulau (Island) Panjang, thousands of dead fish were floating around on the seas.

7:00 p. m. Talu, Ophir District, Lubuk Sikaping Division, Padangsche Benedenlanden Residency. Very violent shocks, which were preceded by a subterranean noise. During the night, 3 shocks followed.

7:30 p. m. Rau, Lubuk Sikaping and Rau District, Lubuk Sikaping Division. The shocks lasted about two minutes. [3])

7:30 p. m. Natal, Natal District and Division, Tapanuli Residency. Very strong quake, which lasted about 4 minutes. The river came out of its banks, so that the water in Kampung Aceh was about 1½ m high.

6:45 p. m. Panyabungan (Penyabungan), Great-Mandailing and Batang-Natal Subdivision, Mandailing and Angkola Division, Tapanuli Residency. Strong quake. 25 shocks were counted until 8:00 a. m. on the 17th. Direction northwest–southeast. The damage done in the whole division was great. Many houses collapsed, rice fields were plowed up equally, and a consequence of the earth slip was that they had to move the Kampung Sialang.

7:00 p. m. Sibolga (Siboga), Sibolga District and Division, Tapanuli Residency. Violent shocks that were transferred in a wavelike motion. Duration 4 minutes. Direction west-southwest to east-northeast or vice versa. [4]) The quake was accompanied by a rolling noise and at various points cracks formed in the soil. Shortly after the first shocks came a tidal wave in the Bay of Tapanuli that twice retired so far that the ships anchored in the harbor came aground. [5])

1861, February 16. 7:00 p. m. Barus, Barus District, Sibolga Division, Tapanuli Residency. Duration of the shocks 4 minutes. They repeated frequently during the night. Direction apparently east–west. The onrushing tide rose no higher than 2-3 feet.

6:30 p. m. Singkil, Singkil Subdivision, [6]) West Coast of Aceh Division, Aceh Government. Violent shocks after some weak shocks had preceded. Duration 10 minutes. Right after the first shocks northwest–southeast oriented cracks began to form, making most of the buildings, including the barracks, uninhabitable. At the same time a tidal wave broke in and flooded the whole place. After it retired, it returned a few more times, but the place was under water, so you could still go in a rowing boat on the market on 25 February. Incidentally an old spill estuary had on occasion of this earthquake reopened and a new river channel formed south of the main estuary. [7])

In the then-independent Batak lands the quake should have also expressed in a violent manner. Some details were later communicated by A. SCHREIBER. [8]) Near Baringin[d], at the source of Aek Mandurana[e] the solfatara [fumarole] was transformed into a lively active bubble. [9])

No start time given. Aceh. Violent earthquake accompanied by tidal waves, which caused much damage in the various ports.

A part of the coast of Susoh, Tapak Tuan Subdivision, West Coast of Aceh Division suffered many changes, including the projecting headland at Ujung Seranggan being swallowed by the waves, so that from the previous situation only the towering trunks of coconut trees could be seen above the water. [10])

1861, February 16, around 6:30 p. m. Nias Island. To Lagundi in the southern parts of the island, the first violent shock, after some minor impacts were noted already days before. Duration about 3 minutes. Shortly afterwards, 3 less violent shocks in northwest–southeast. Around 6:45 a huge tidal wave rolled against the southeast coast and there reached a height of about 7 m. By 8:30 most buildings were already washed away, with 50 deaths.

In the capital Gunungsitoli lying on the northeast coast the quake began at 6:45, also with great violence. Direction southeast–northwest or vice versa. The sea retreated by 32 m, whereupon it stormed back with great force against the coast and in the process destroyed several beach villages. Also ships were thrown on the beach. On the west coast several cliffs came to the fore and the small island Lapau [11])[f] was almost entirely connected to the north side of Nias.

Also strongly affected were the Batu Islands. On Pulau Telo shocks began at 7:00 p. m. and lasted for 5 minutes but weaker ones were still being observed throughout the whole night. An hour after the first shock a tidal wave rolled against the beach and lay all villages under water. During the night of the 16th–17th one could notice the tide ebb and flow four times. [12]) Other islands of this group suffered greatly, particularly Pulau Simuk (Simo), lying at 0°5' S, 97°52' E, erroneously referred to as Pulau Kalapa, [13]) at which the tidal wave had shown before the start of the shocks.[g] The worst was between Simuk (Simo), Babanirege and Lakao [14])[h] areas. Of the 120 houses, 96 were destroyed, and a count of the 1045 souls, a population of 675, also 103 foreigners, lost their lives. Of the 282 inhabitants of Kampung Babanirege alone 205 on the run from the wave were washed away. [15])

Blocks of rock were flung inland by the wave 100 and even 200 steps. [16])

Furthermore, a seaquake was observed on the open seas in several places. The American ship “Humboldt” felt a kick in the height of the island Simeulue (Simalur), which is also near the west coast of Sumatra; the Dutch ship “Vesta”, Captain GERREBRANDS such [?] in the height of Pageh- (actually Pagai-) Islands below 0°30' S, 97° E.[i] [17]) The Dutch Corvette “Princess Amalia” on the journey from Singkel after Aceh, observed a shock and a trembling of the ship. [18])

While lacking any message, oddly enough, from the east coast of Sumatra, a shock was felt on the Malay Peninsula as well as in Singapore [19]) and from the last-mentioned places, more specifically, it was reported that at 7:34 p. m. an undulating quake had occurred, which lasted about 2 minutes. Direction southwest–northeast. [20])

7:30 p. m. Penang (Pulau Pinang). Violent wavy quake, at the same time 3 shocks could be distinguished. Direction north–south. About 5 minutes before the occurrence of the earthquake, an extraordinary movement of the sea was noticed. [21])[j]

7:35 p. m. Jepara, Jepara District and Division, Semarang Residency. Some shocks. Direction south–north, but partly southwest–northeast. [22])

[1]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 114.

[2]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 116.

[3]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 116–117.

[4]) J. J. DE WILDE. (Topographical sketch of Sibolga. Geneesk. Tijdschr. Ned. Ind. *11*. Batavia 1864, p. 110) gives as the direction S/S–N/E and says that at the end of the quake vertical shocks also occurred.

[5]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 118.

[6]) At that time belonging to the Tapanuli Residency.

[7]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 118–119.

[8]) The southern Batta lands in Sumatra. Petermanns Mittlg. *12*. Gotha 1876, p. 68. Erroneously, the quake is stated as occurring in 1862.

[9]) More recently, this was known as a hot mud source, as occurred 17 May 1892, as a result of an earthquake, again with violent surging.

[10]) K. F. H. VAN LANGEN. Aceh's west coast. Tijdschr. K. Nederl. Aardr Genootsch. (2) *5*. M. U. A. 1888, p. 225.

[11]) An island of that name is not found on the maps of Nias. The only thing that could come into consideration for the present case would be Ganeu, lying at 1°24½' N, 97°12',8 E, which is close to the beach and is connected to it by a reef.[f]

[12]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Indië *25*. Batavia 1863, p. 120.

[13]) Pulau Kalapa would mean Cocos Island, but in this case is probably a corruption on the British nautical charts encountered before Klapps Iceland [?].

[14]) L. HORNER calls the localities mentioned Limo (misprint for Simo), Bawaniregeh and Laguo (Batu Islands, located to the west of Sumatra. Tijdschr. voor Neêrl. Indië *3*. l. Batavia 1840, p. 341).[h]

[15]) According to L. HORNER, at the end of 1837 Simuk island possessed a population of 513 souls, so they must have experienced a doubling by 1861.

[16]) An Earthquake in the East at Simo. Nautic. Magazine. London 1861, p. 553, — ALEXIS PERREY. Additional note . . . . to a memoir on earthquakes in Sumatra. Nouv. Ann. des Voyages (6) *7*. Part IV. Paris 1861, p. 42–43.

[17]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Indië *25*. Batavia 1863, p. 121. — Communications from the journals published by the Royal Meteorological Institute. Utrecht 1867, p. 16, 2nd edition 1896, p. 68.

[18]) Pertinent Report of the Operations of the Dutch Navy in the East Indies, during the year 1861. Verhandel. en berigten betr. het Zeewezen *24*. 2. Amsterdam 1864, p. 218.

[19]) H. N. R(IDLEY). Earthquake in the Malay Peninsula. Journ. Strait Branch R. Asiatic Soc. N°. *25*. 1894. Singapore, p. 169.

[20]) (F.) DE CASTELNAU. Earthquake in Singapore 16 February 1861. Compt. rend. Acad. des Sc. *52*. Paris 1861, p. 881–882.

[21]) J. M. GILLISS. Earthquake in the Island of Penang. Amer. Journ. of Sc. (2) *32*. New Haven 1861, p. 297.

[22]) M. TH. REICHE. On earthquakes and other natural phenomena. Natuurk. Tijdschr. Ned. Ind. *25*. Batavia 1863, p. 113.

[a] *Cribb [2010] locates late-19th century Padangsche Benedenlanden as roughly the coastal portion of present-day West Sumatra province.*

[b] *Cribb [2010] locates late-19th century Padangsche Bovenlanden as roughly the inland portion of present-day West Sumatra province.*

[c] *This likely refers to Mount Marapi, just east of Mount Singgalang, in present-day West Sumatra province.*

[d] *Baringin is one of the villages presently in the subdistrict Sipirok, South Tapanuli, North Sumatra, Indonesia.*

[e] *Aek Mandurana is a stream in North Sumatra, Indonesia.*

[f] *Assuming the coordinates in footnote 11 of Wichmann refer either to 1°24.5′ N, 97°12.8′ E or to 1°24.5′ N, 97°12′8″ E, there is no land at those precise coordinates, but that could be due to differences of up to 1 or 2 km between WGS84 and earlier reference frames. However, there is a stream presently named Lafau at 1°24.2′ N, 97°12.7′ E (WGS84), and a nearby piece of land at 1°24.6′ N, 97°11.4′ E (WGS84) was an island (but connected to mainland Nias by a reef) before the 2005 earthquake but became a peninsula following the 2005 uplift. Various nautical charts and other available maps show an island named Pulau Lafau at 1°25.4′ N, 97°13.1′ E (WGS84), but it is not connected to Nias even after the 2005 uplift. A location named Ganeu at 1°24.4′ N, 97°11.9′ E (WGS84) was already connected to mainland Nias just prior to the 2005 uplift.*

[g] *Surely this statement about the tsunami hitting the island before the start of shaking is incorrect (or exaggerated), but the tsunami could have hit Simuk more quickly than at other places.*

[h] *No islands or locations with names similar to Babanirege or Lakao, or to Bawaniregeh or Laguo (see Wichmann's footnote 14), could be found.*

[i] *This location must be in error.*

[j] *It is unclear what is meant by "an extraordinary movement of the sea," but it is unlikely that it describes a tsunami before the earthquake shaking was felt locally. Penang should be fairly well protected from an 1861 tsunami source.*

Note: All numbered footnotes for this source were copied and translated from the original, except that they have been renumbered here to be sequential. Lettered footnotes were added by us. There is much overlap between the information in this source and that in the Singapore Free Press *accounts (also included in this Appendix), though there are a few minor inconsistencies. In the translation, we updated numerous place names to their (modern) Indonesian spellings; see the original, above, for Wichmann's original spelling.*

Note: The following sources, which are cited by Wichmann, are not included in their original form in this Appendix, but they are available online:

Natuurkundig Tijdschrift voor Nederlandsch Indië 25. *Batavia, 1863:*

http://babel.hathitrust.org/cgi/pt?id=hvd.32044106269608;view=1up;seq=7 or
http://babel.hathitrust.org/cgi/pt?id=hvd.32044106345838;view=1up;seq=7

Tijdschrift voor Nederlandsch Indië 3. *Batavia, 1840:*

http://books.google.com/books?id=ALU8AAAAYAAJ&pg=PA341

The Nautical Magazine and Naval Chronicle for 1861. London, 1861:

http://books.google.com/books?id=SjpGQLU17akC&pg=PA553 or
http://ebooks.cambridge.org/chapter.jsf?bid=CBO9781139424868&cid=CBO9781139424868A014

Nouvelles Annales des Voyages, Série 6, Année 7, *Tôme 4. Paris, 1861:*

http://babel.hathitrust.org/cgi/pt?id=nyp.33433000871297;view=1up;seq=50

Verhandelingen en Berigten Betrekkelijk het Zeewezen, de Zeevaartkunde, de Hydrographie, de Koloniën, en de Daarmede in Verband Staande Wetenschappen 24. *Amsterdam, 1864:*

http://books.google.com/books?id=Qp8AAAAAMAAJ&pg=RA1-PA213 or
https://archive.org/details/verhandelingene07unkngoog

Journal of the Straits Branch of the Royal Asiatic Society 25. *Singapore, 1894:*

http://biodiversitylibrary.org/page/41714480 or
https://archive.org/details/journalofstra25271894roya

Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences 52. *Paris, 1861:*

http://gallica.bnf.fr/ark:/12148/bpt6k3009c/f879.image.langFR

The American Journal of Science and Arts, Series 2, 32. *New Haven, 1861:*

http://biodiversitylibrary.org/page/37026624 or
https://archive.org/details/mobot31753002152590

1907 Historical Account #1

***The Sydney Morning Herald*, 24 January 1907 (Thursday morning).**

p. 7, column 1:

THE EARTHQUAKES.
CALAMITY OFF SUMATRA.
FIFTEEN HUNDRED DEATHS.

LONDON, Jan. 23.

Details of the tidal wave which devastated the southern coast of Pule Babi[1], an island off the west coast of Sumatra, are to the effect that 1500 people perished, and the whole southern coast has been destroyed.

The island has nearly disappeared.

Shocks of earthquake continue daily in the island.

Pulo Babi[1] is the most northerly of the islands off the west coast of Sumatra, and is situated about 70 miles from the mainland. It is not simply of volcanic origin, but exhibits the older rocks of the main island, granites and sandstones, and possesses, roughly speaking, its fauna; although the larger animals, such as the tiger, elephant, and rhinoceros, are, as might be expected, wanting. Of Pulo Babi[1], which is also known as Si Malu[1], or Hog Island, not much is known. The inhabitants are partly Achenese and partly descendants of Menangkabe settlers, and profess the Mohammedan religion, but they are almost savages, and the Dutch have not attempted to establish a settlement on the island, which was, previous to the catastrophe reported this morning, about 60 miles in length by 20 in breadth.

[1] *Although Pulau Babi is now the name given to a smaller island at 2.09°N, 96.65°E, the description in this article of the island's location and dimensions, along with the reference to an alternate name of "Si Malu" (Simeulue), clearly indicates the article describes events that took place on the larger island of Simeulue. Cribb [2010] further notes that, in addition to Simaloer (and Simalur), older names for Simeulue include "Babi" and "Hog" Island.*

Note: Available at http://nla.gov.au/nla.news-article14798014

1907 Historical Account #2

Great Britain Hydrographic Department (1934), *Malacca Strait Pilot, Comprising Malacca Strait and its Northern Approaches, Singapore Strait and the West Coast of Sumatra*, Second Ed., Hydrographic Dept., Admiralty, London.

p. 256, lines 7–20:

SIMALUR[1].—Simalur, the northernmost of the large islands off the west coast of Sumatra, lies with its south-eastern point 71 miles westward of Ujong Pasir Gala. Sibau, 2,051 feet ($625^{m}1$) high, the highest peak of the island, lies on the north-eastern side about 18 miles north-westward of Ujong Matankeli, the south-eastern point; Sanulok, the highest peak at the north-western end, is 1,476 feet ($449^{m}9$) high, and may be identified by a small clump of trees rising above the others.... Sinabang, the principal harbour, lies on the north-eastern side of the island, at the south-eastern end. The island is everywhere wooded, as are most of the islands off-lying it.

Earthquakes and tidal waves occasionally occur, but minor shocks are frequent. In 1907, the south coast was partially submerged by an earthquake.

[1] *Simalur and Simaloer are older names for the island of Simeulue [Cribb, 2010].*