

APPENDIX TO

LONG SWARMS AND SHORT SWARMS AT VOLCANOES: EVIDENCE FOR DIFFERENT PROCESSES

Stephen R. McNutt¹

¹ University of South Florida, School of Geosciences, Tampa, Florida, USA

Appendix A

Appendix Kasatochi

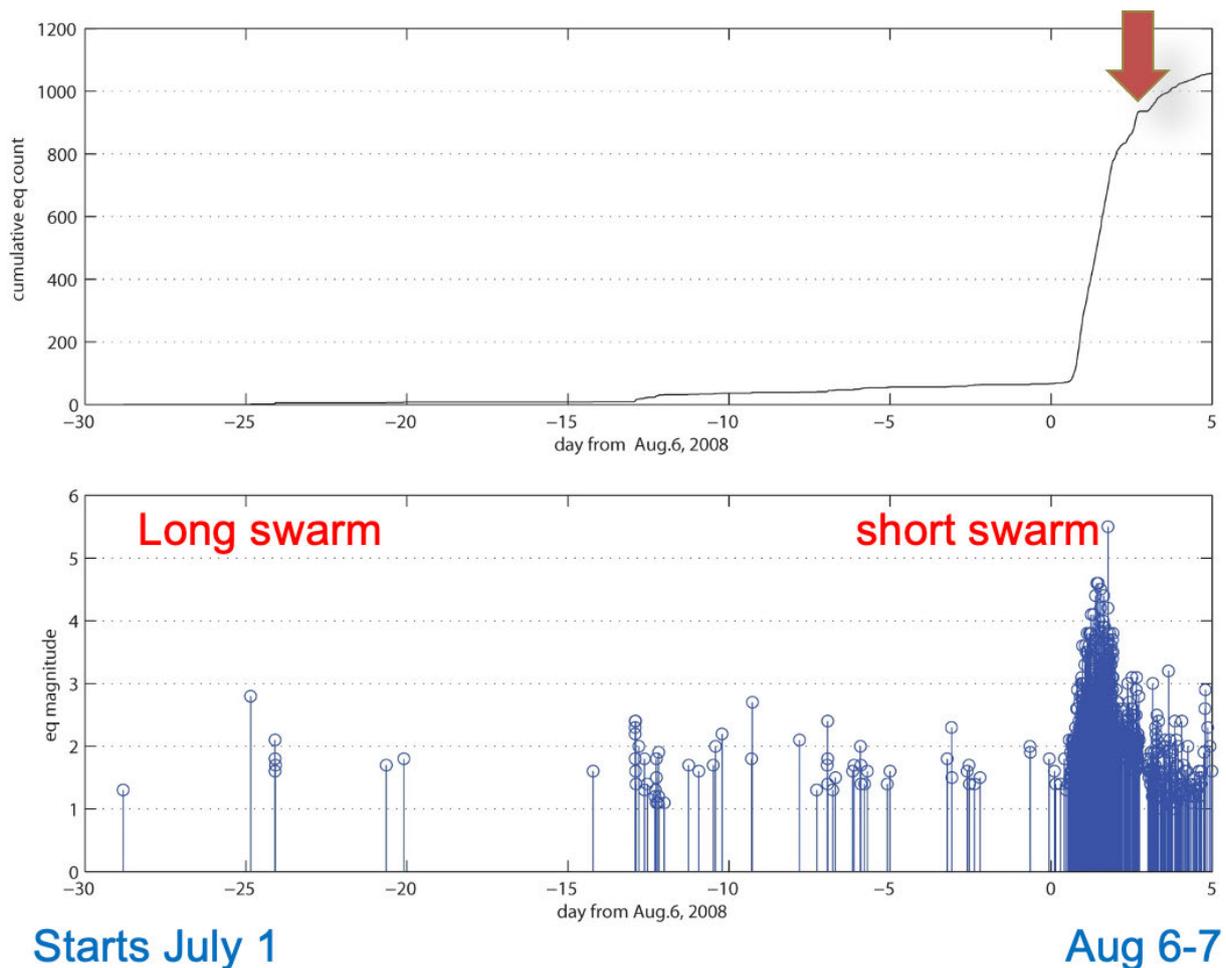


Figure A1. Kasatochi time series of earthquakes. Top: cumulative number of events; arrow marks onset of eruption. Bottom: earthquake magnitudes versus time. The long swarm lasts from 1 July to 6 August, 2008. The short swarm occurred 6-7 August. Modified from Ruppert et al. (2011).

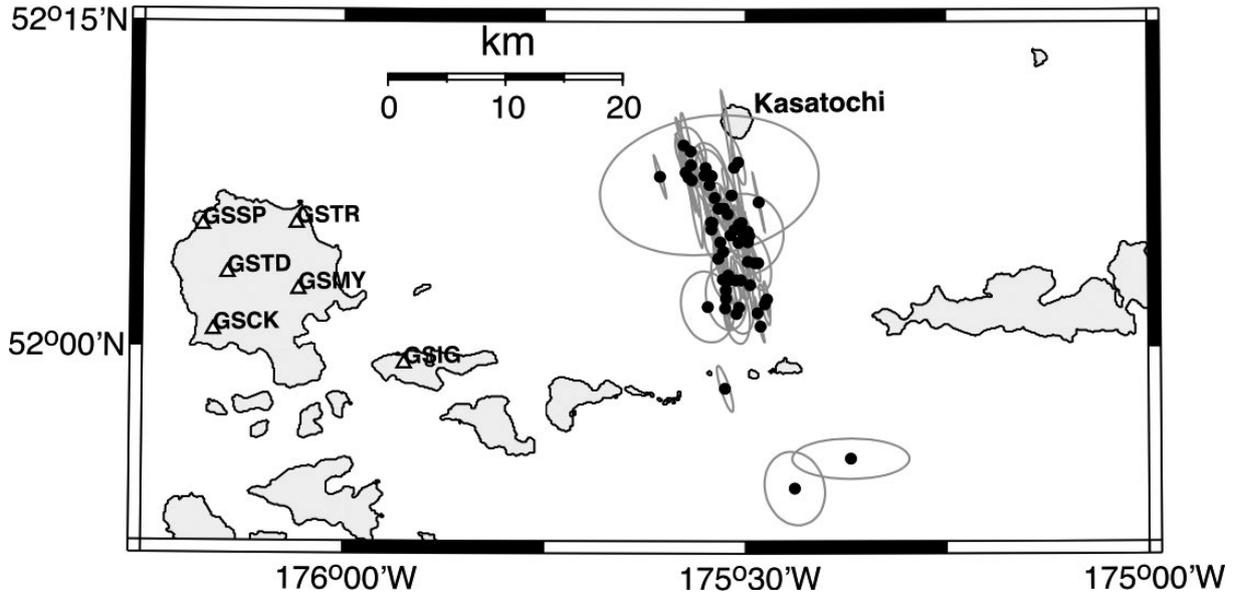


Figure A2. Kasatochi earthquake locations (dots). 68% error ellipses are shown; these are elongated N-S because the stations (triangles) are all located E or W and control in the N-S directions is poor. After Ruppert et al. (2011).

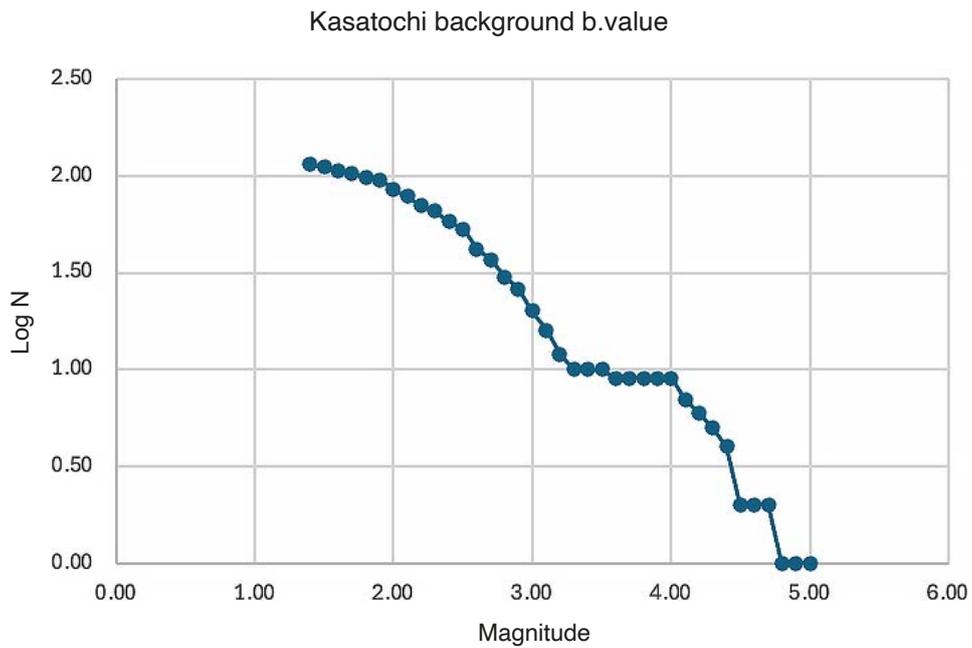


Figure A3a. A b-value plot (cumulative log N versus magnitude) for the background seismicity at Kasatochi Volcano. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

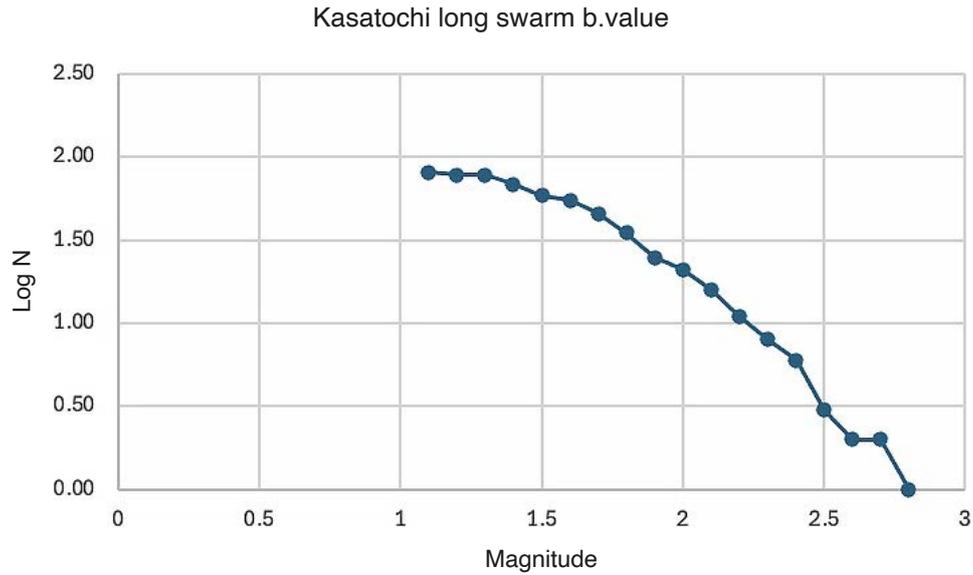


Figure A3b. A b-value plot (cumulative log N versus magnitude) for the long swarm at Kasatochi Volcano. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

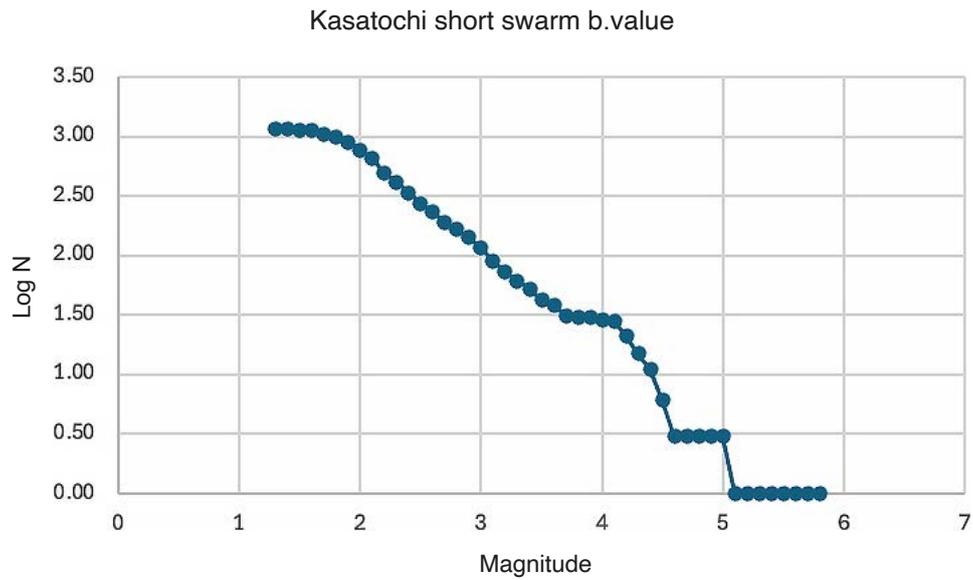


Figure A3c. A b-value plot (cumulative log N versus magnitude) for the short swarm at Kasatochi Volcano. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

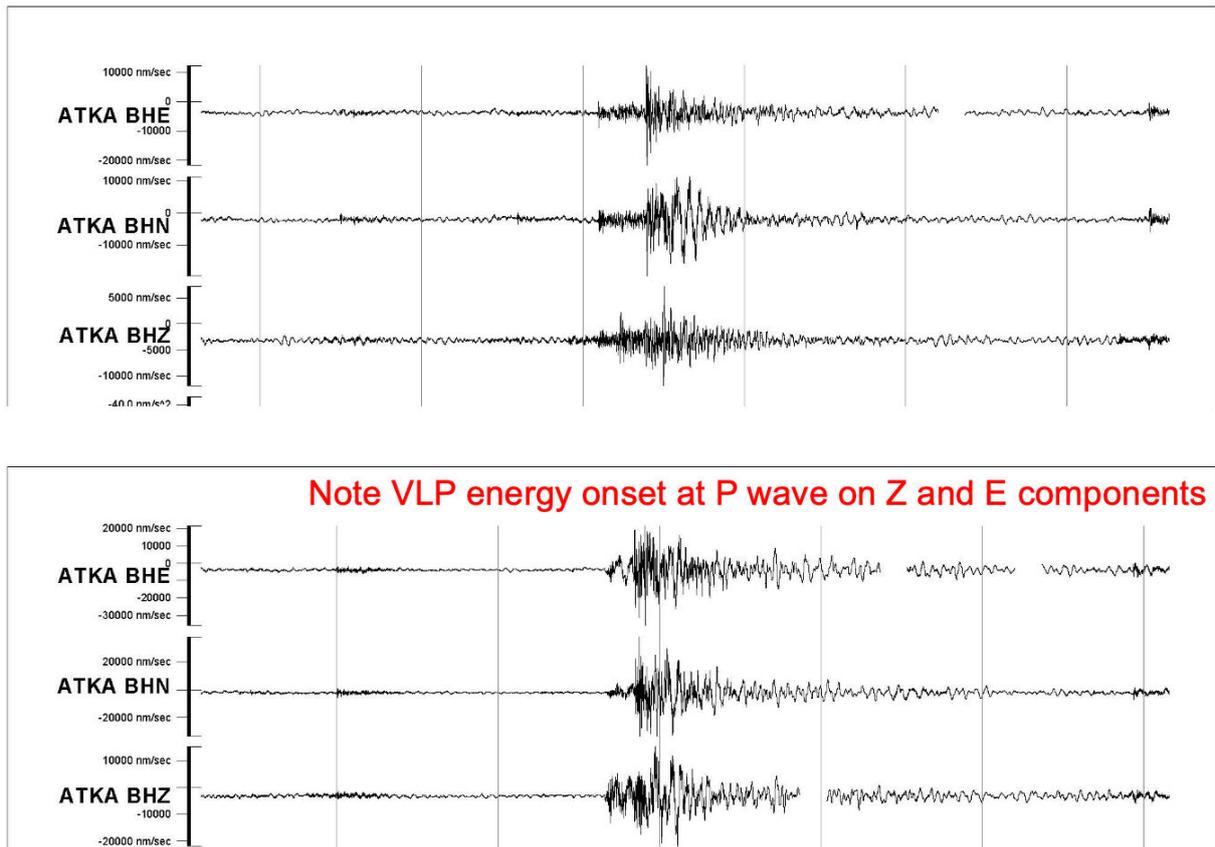


Figure A4. Seismograms from 3-component broadband station ATKA, 88 km to the east. The top panel shows a typical regional earthquake (M3.0, 52.151N, 175.508W, 7.8 km, 7 August 2008, 00:11 UTC); note the large S waves and the small P waves. The bottom panel shows an event from the Kasatochi short swarm (M3.5, 52.096N, 175.471W, 2.9 km, 7 August 2008, 03:21 UTC); strong VLP energy is obvious in the Z and E components. The VLP portion of the signal is larger on E than N component because of the geometry of the station with respect to the volcano. Each seismogram shows 6 minutes of data; vertical lines are 1 minute apart. Components are labeled BHE (east-west), BHN (north-south), and BHZ (vertical).

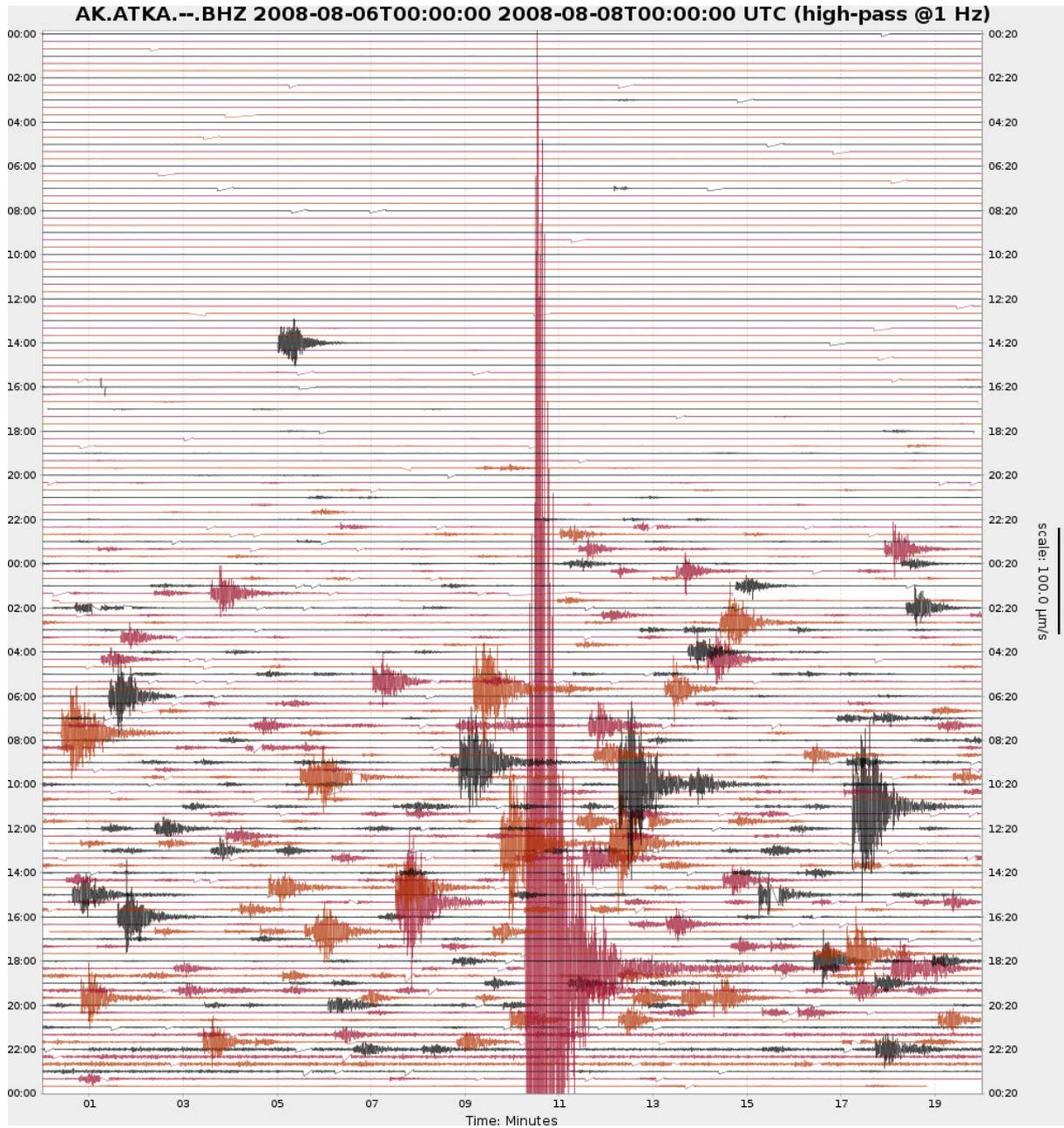


Figure A5. Seismogram from station ATKA vertical component showing 2 days of data. The short swarm starts at about 1800 UTC on 6 August 2008. The largest event (red) was a M5.8 earthquake that occurred 3.5 hrs before the eruption onset.

Appendix Spurr

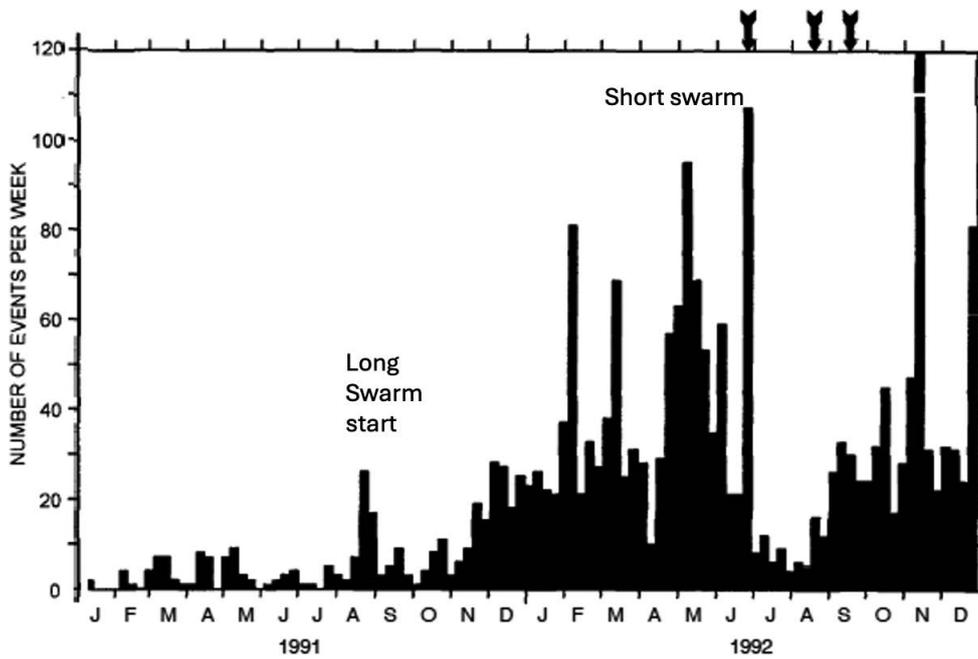


Figure A6. Time series of number of earthquakes per week for Mount Spurr. The onsets of the long swarm and short swarm are labeled. The arrows show the three eruptions on June 27, August 19, and September 17, 1992. Modified from Power et al. (1995).

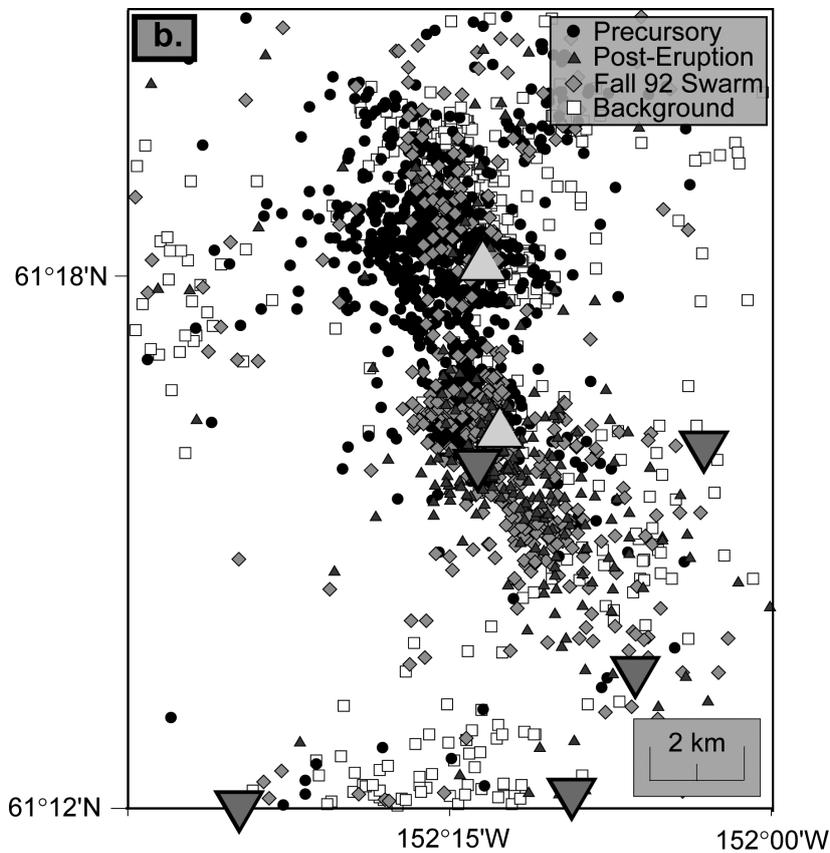


Figure A7. Map of earthquake locations at Mount Spurr. Triangles are seismic stations. The active vent, Crater Peak, is at the center of the image. From Roman et al. (2004).

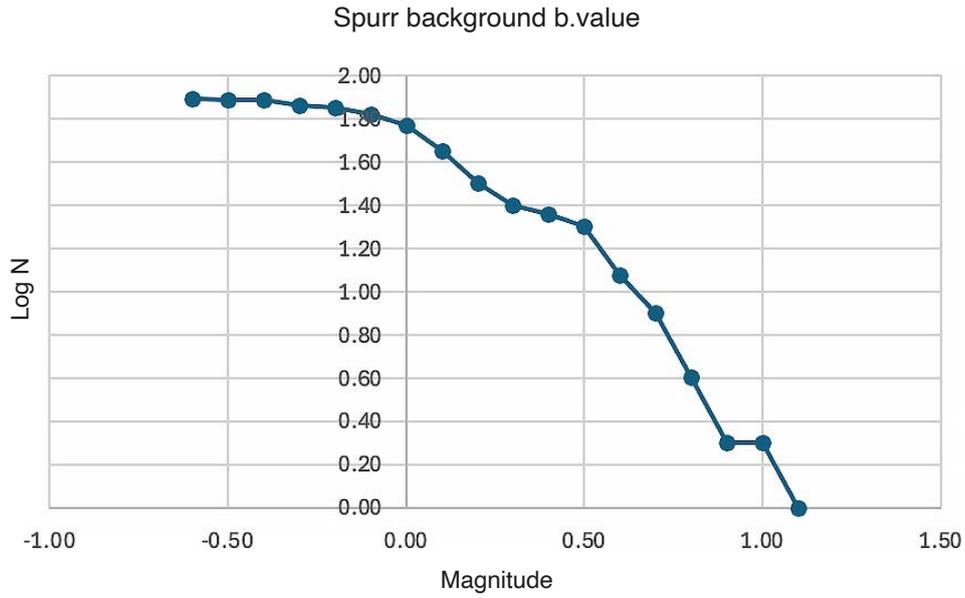


Figure A8a. A b-value plot (cumulative log N versus magnitude) for the background seismicity at Mount Spurr. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

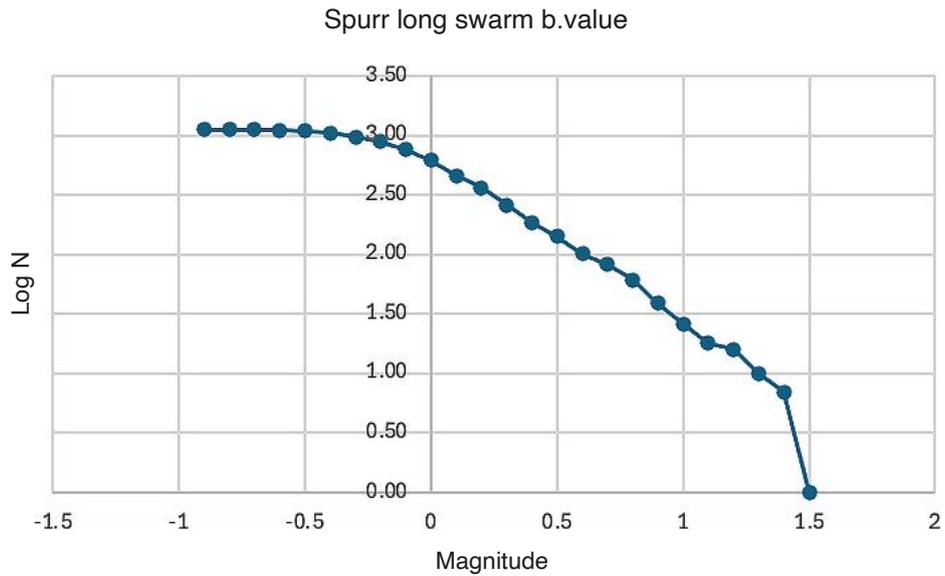


Figure A8b. A b-value plot (cumulative log N versus magnitude) for the long swarm at Mount Spurr. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

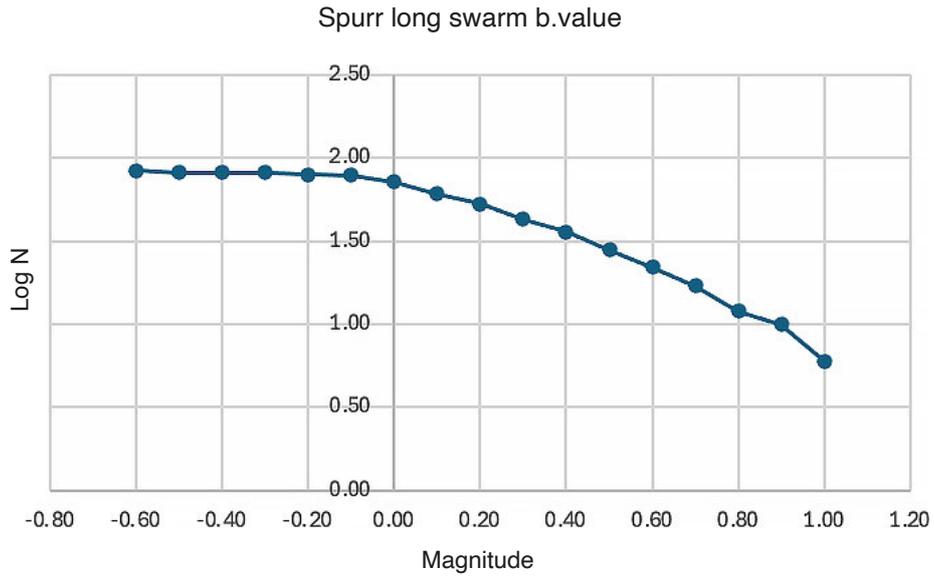


Figure A8c. A b-value plot (cumulative log N versus magnitude) for the short swarm at Mount Spurr. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

Appendix Rabaul

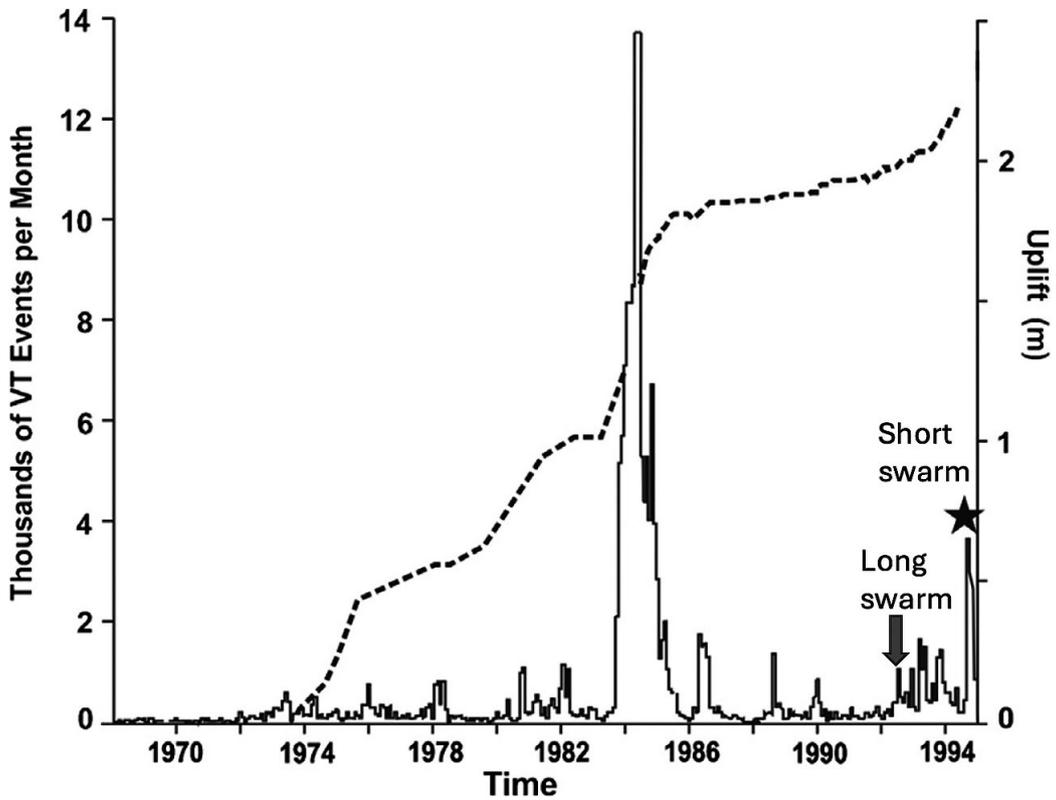


Figure A9. Time series of Rabaul seismicity and uplift from 1968-1994. The long swarm and short swarm are labeled. The star marks the onset of the eruption. Modified from McKee et al. (2018).

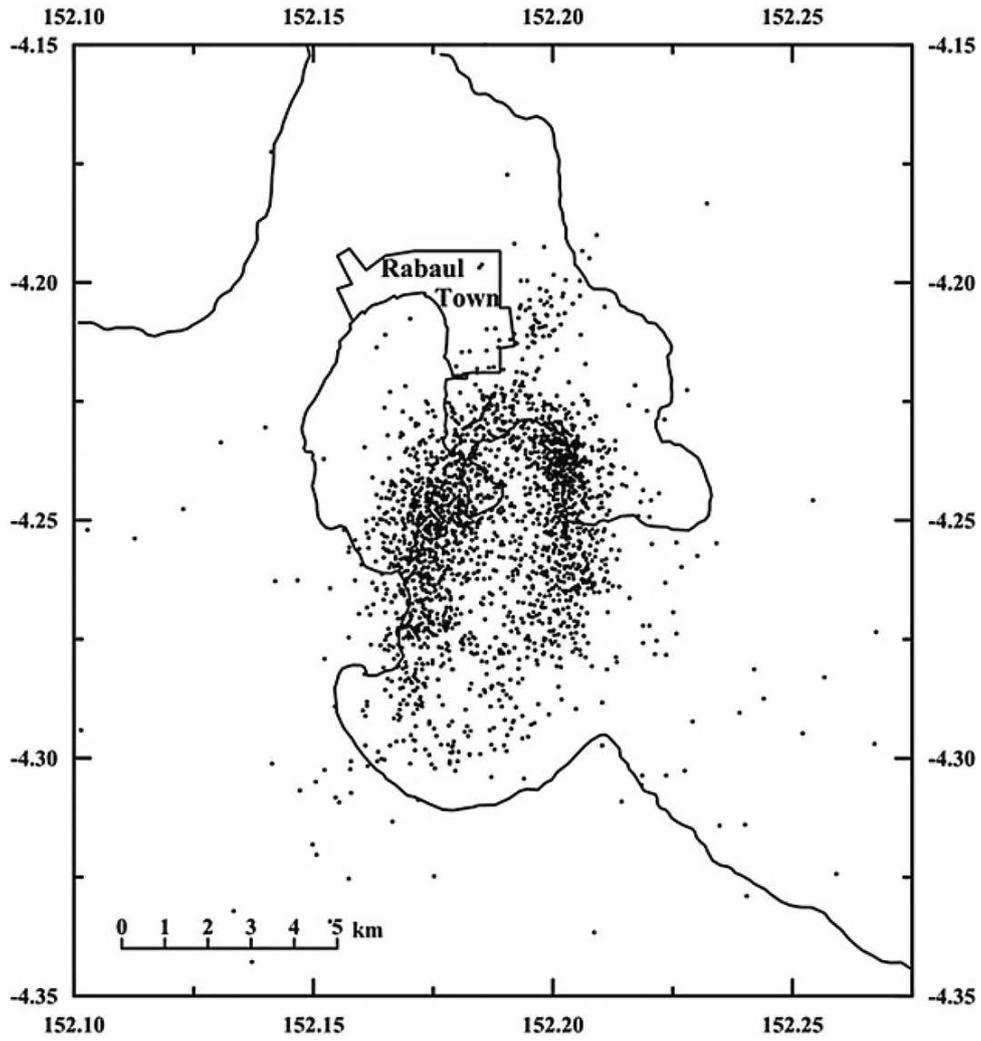


Figure A10. Epicentral map of Rabaul caldera and surrounding area for the time period 1971 to 1983. From McKee et al. (2018).

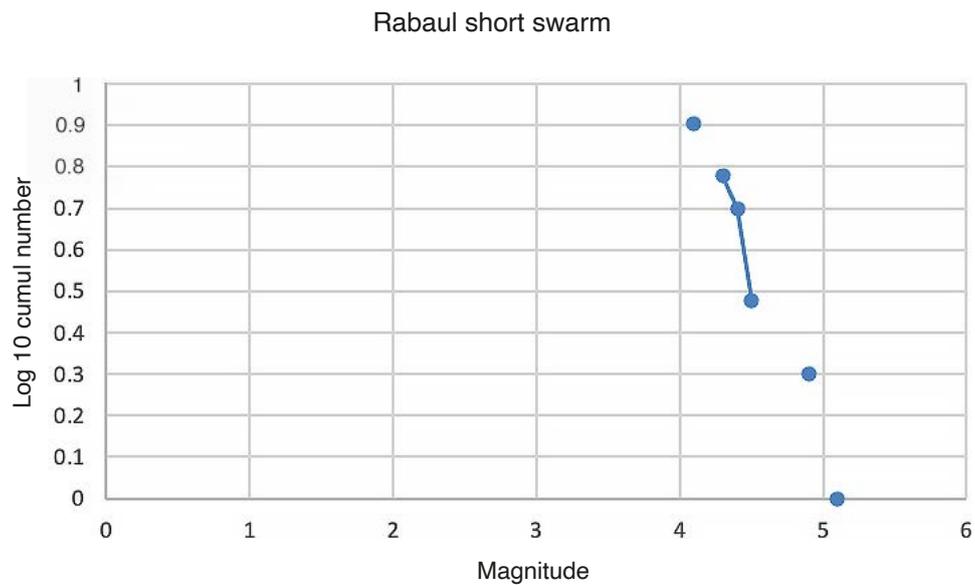


Figure A11. A b-value plot (cumulative log N versus magnitude) for the short swarm at Rabaul caldera. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

Appendix Okmok

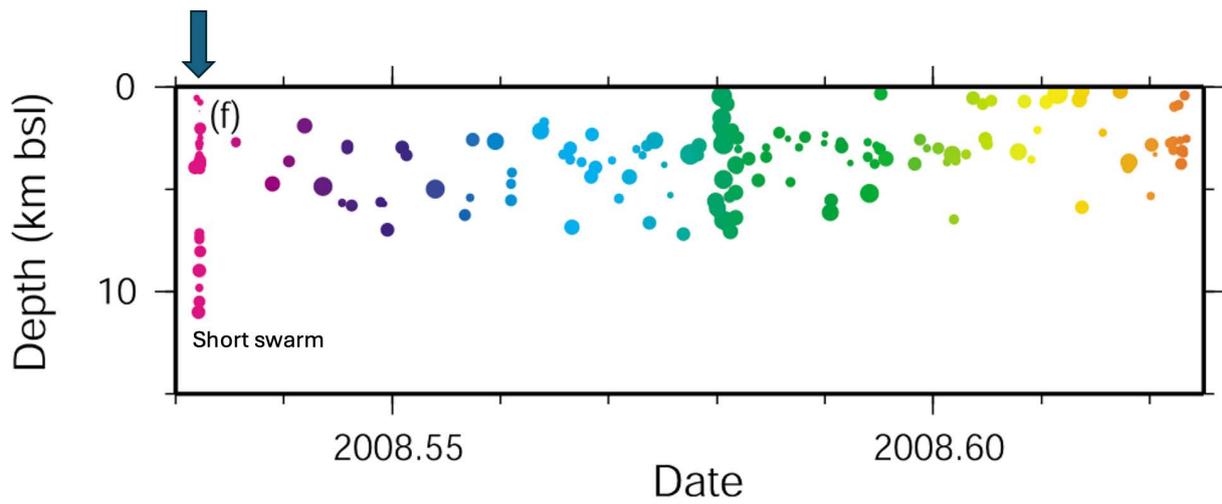


Figure A12. Time depth plot for Okmok from 11 July–15 August 2008. The short swarm is labeled. Arrow marks the 12 July 2008 eruption. Modified after Johnson et al. (2009).

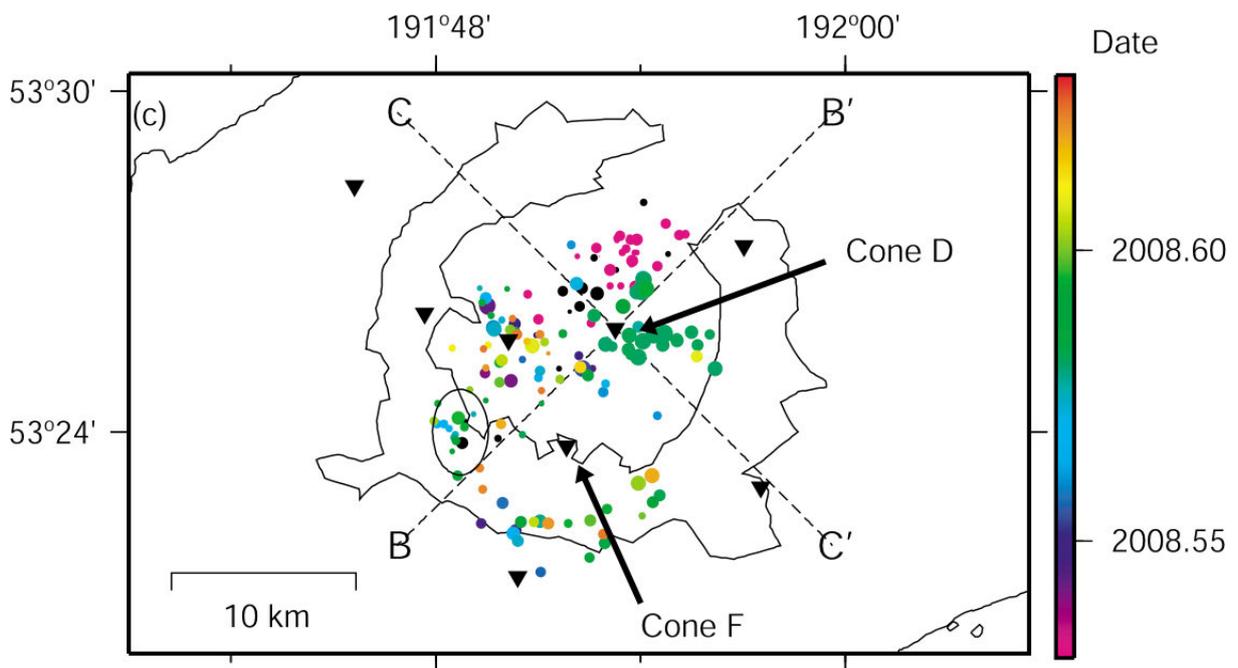


Figure A13. Map of epicenters at Okmok volcano based on the same data from figure A12. The new vent was just SW of Cone D. Source Johnson et al. (2009).

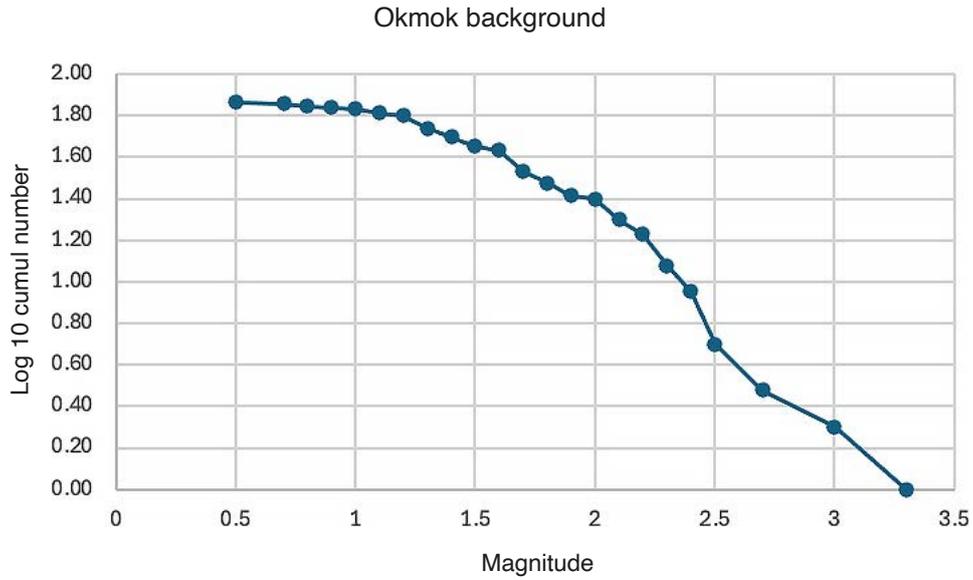


Figure A14a. A b-value plot (cumulative log N versus magnitude) for the background seismicity at Okmok Volcano. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

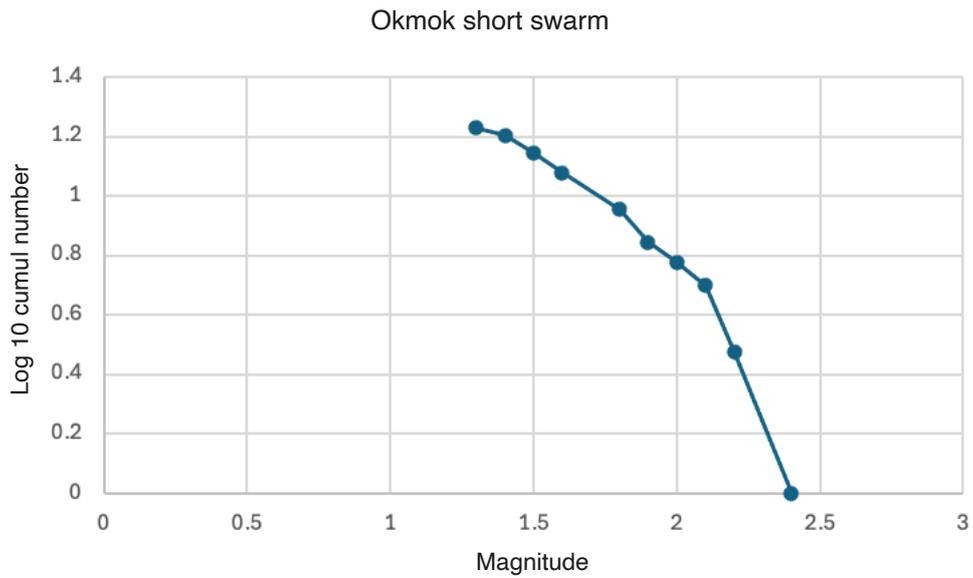


Figure A14b. A b-value plot (cumulative log N versus magnitude) for the short swarm at Okmok Volcano. The b-value, dates and number of events are given in Tables 2 and 3. Line segments connecting data points are a plotting artifact and are not relevant.

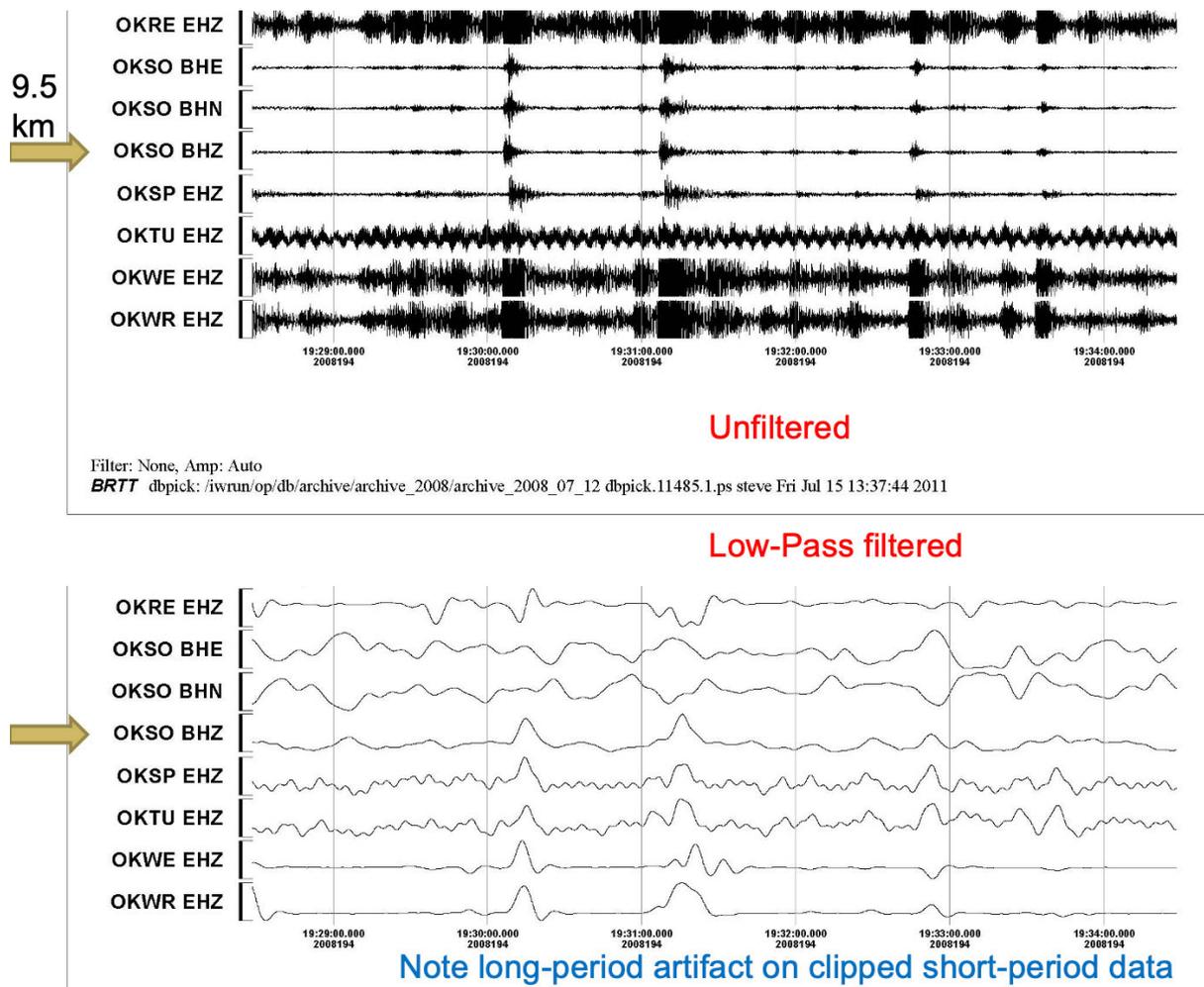


Figure A15. Seismograms from several stations in the Okmok network. Top unfiltered; bottom-low-pass filtered. Note the broadband station OKSO. Small earthquakes ($M \sim 1$) in the top panel are shown to have VLP energy after filtering (bottom panel). Several events for the bottom two short-period stations (OKWE and OKWR) are clipped; the filtering produces a well-known long period artifact.

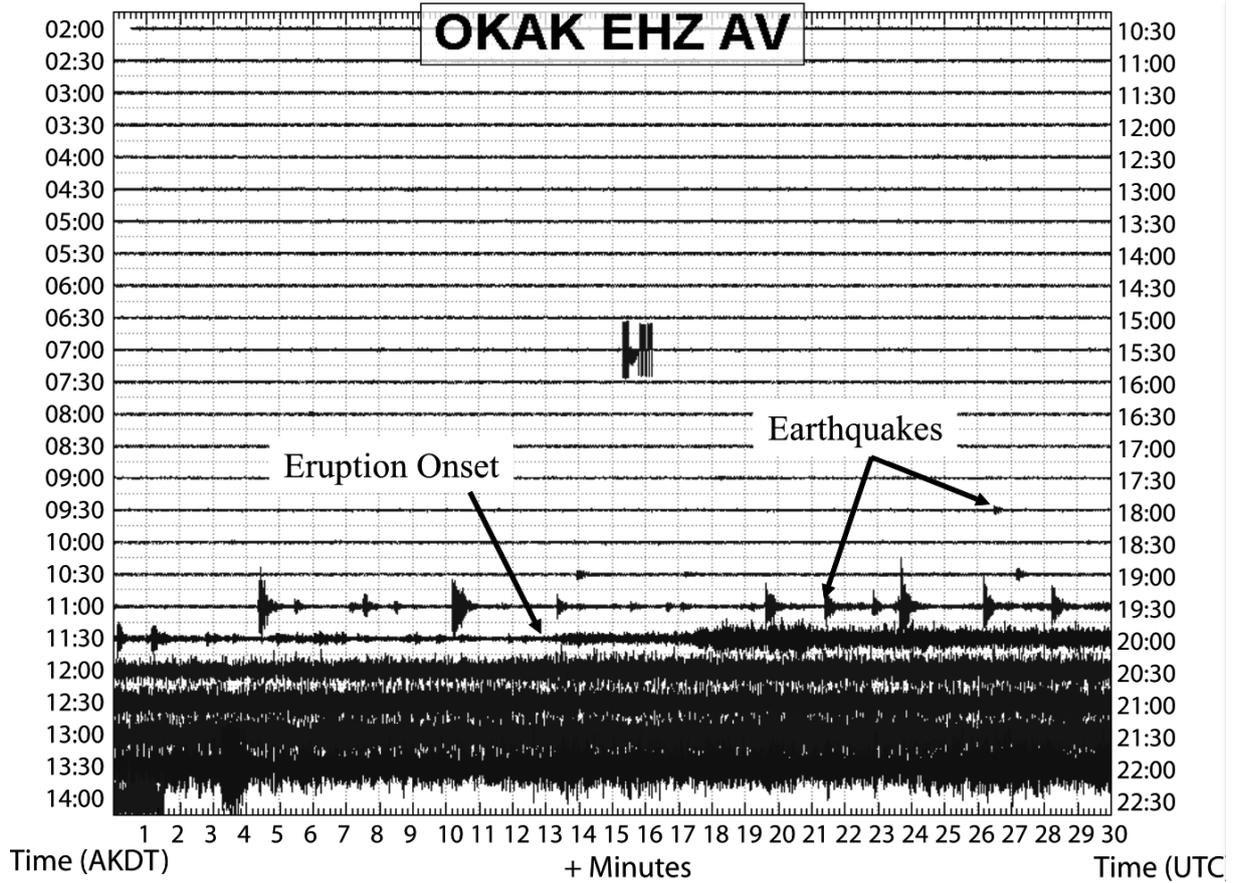


Figure A16. Seismogram from short-period station OKAK. Individual earthquakes of the short swarm are clear. The eruption onset is also labeled. The signal at 7:15 AKDT is a calibration pulse. After Johnson et al. (2009).

Appendix Augustine

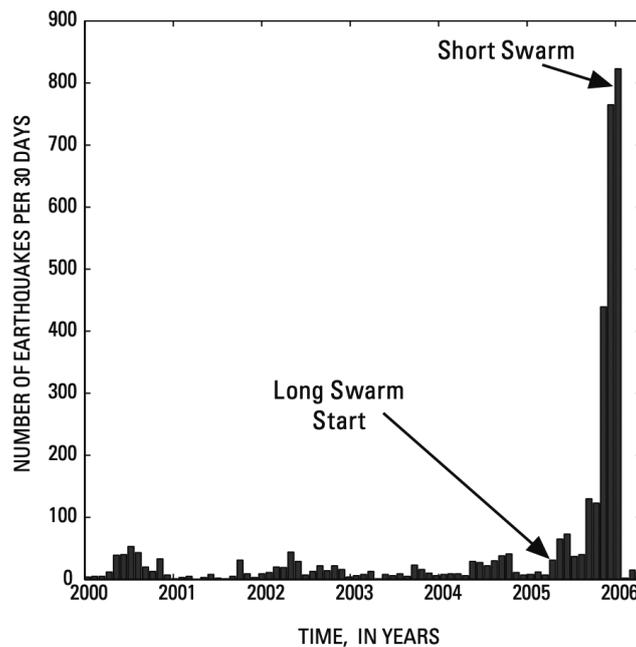


Figure A17. Number of earthquakes versus time for Augustine Volcano showing the onset times of the long swarm and short swarm. After Jacobs and McNutt (2010).

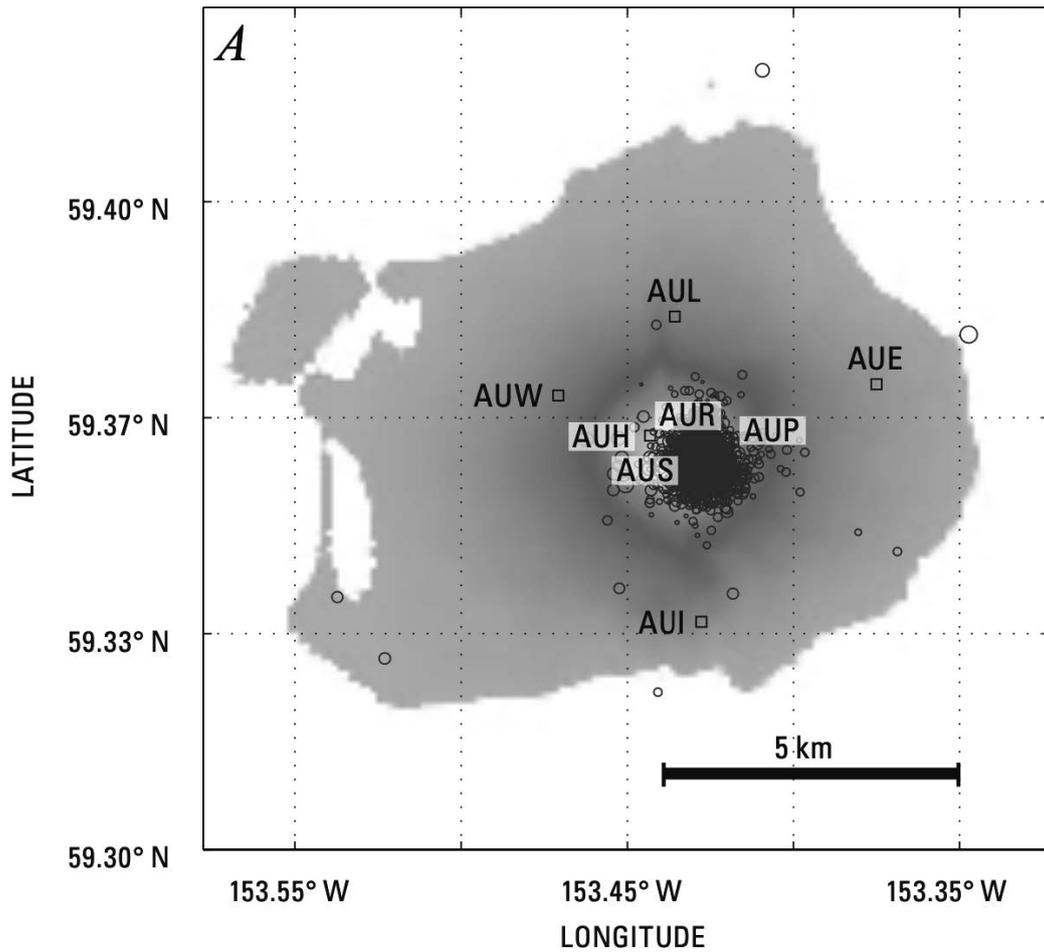


Figure A18. Map of epicenters for the Augustine swarm. Nearly all the earthquakes occurred in a small volume beneath the summit. After Jacobs and McNutt (2010).

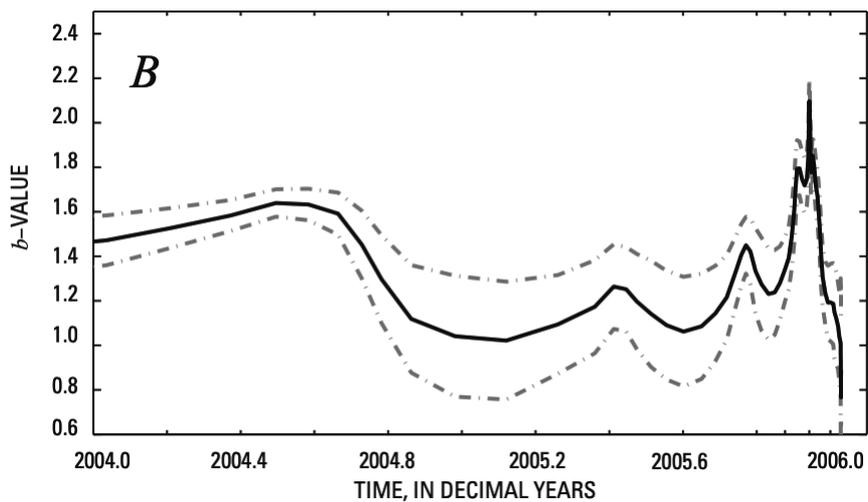


Figure A19. Augustine b-values versus time. Dashed lines are 95 percent confidence values. After Jacobs and McNutt (2010).

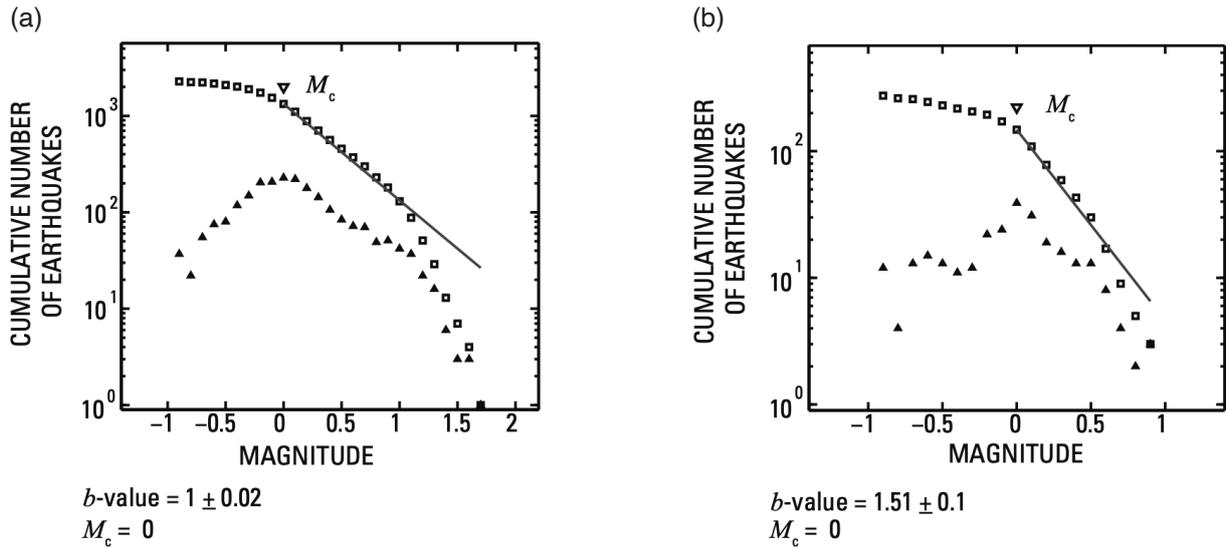


Figure A20a. Cumulative frequency plots of Augustine earthquakes from January 1, 2000 to the initial eruption on January 11, 2006 with derived b -values. Triangles and squares show the number of earthquakes at each magnitude and the cumulative number of earthquakes, respectively. The magnitude of completeness (M_c) is shown by an inverted triangle; errors in b -value calculations reflect the 95-percent confidence interval of the maximum likelihood solution. (a) The entire AVO earthquake catalog (January 1, 2000 to January 11, 2006). (b) The background (January 1, 2000 to April 29, 2005). After Jacobs and McNutt (2010).

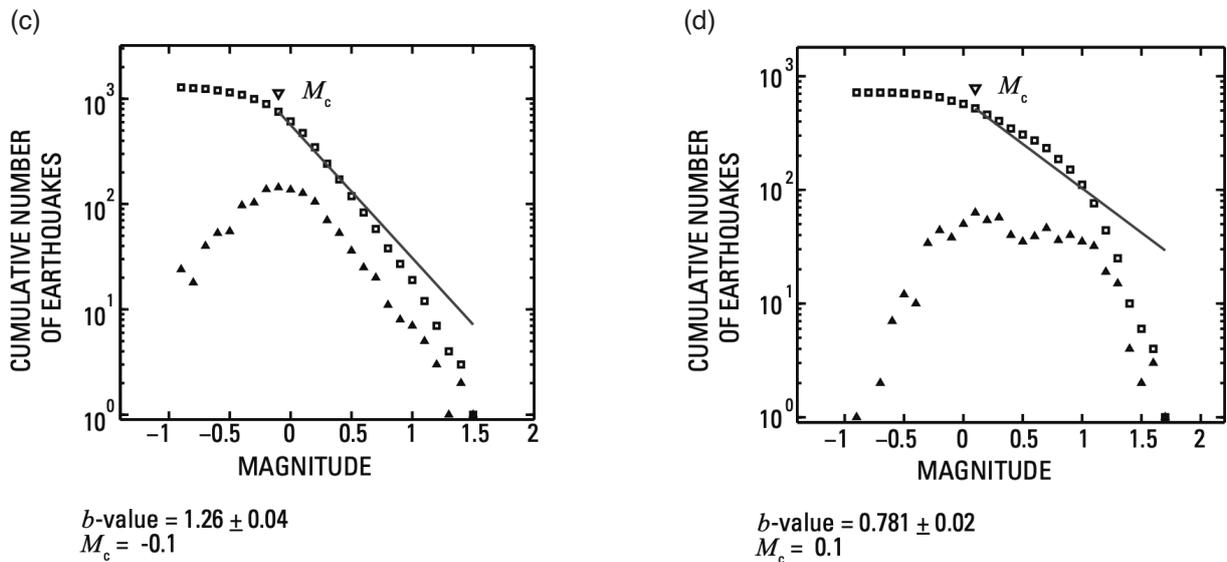


Figure A20b. Same as Fig. 20a but for (c) The long swarm (April 30, 2005 to January 10, 2006). (d) The short swarm (13 hours prior to the initial eruption on January 11, 2006). After Jacobs and McNutt (2010).

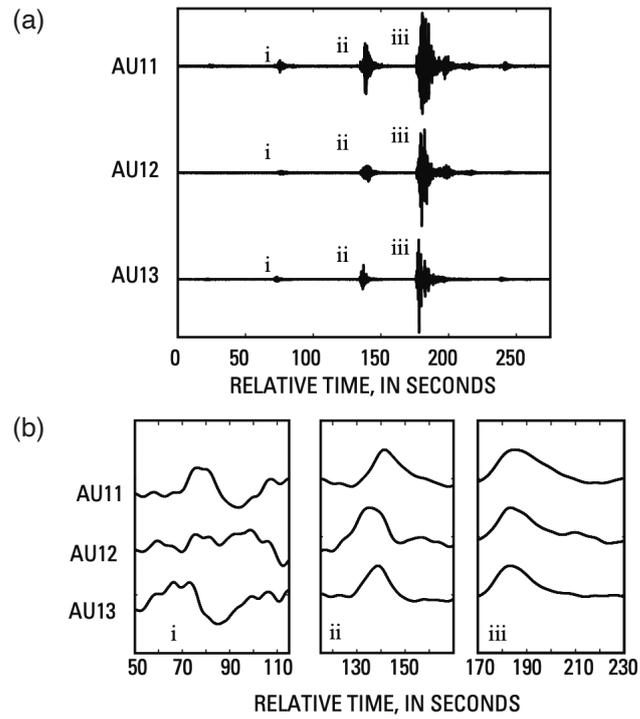


Figure A21. Three earthquakes from the short swarm. (a) The three events i, ii, and iii on three broadband stations. (b) Filtered data showing VLP energy on three different stations. After Jacobs and McNutt (2010).

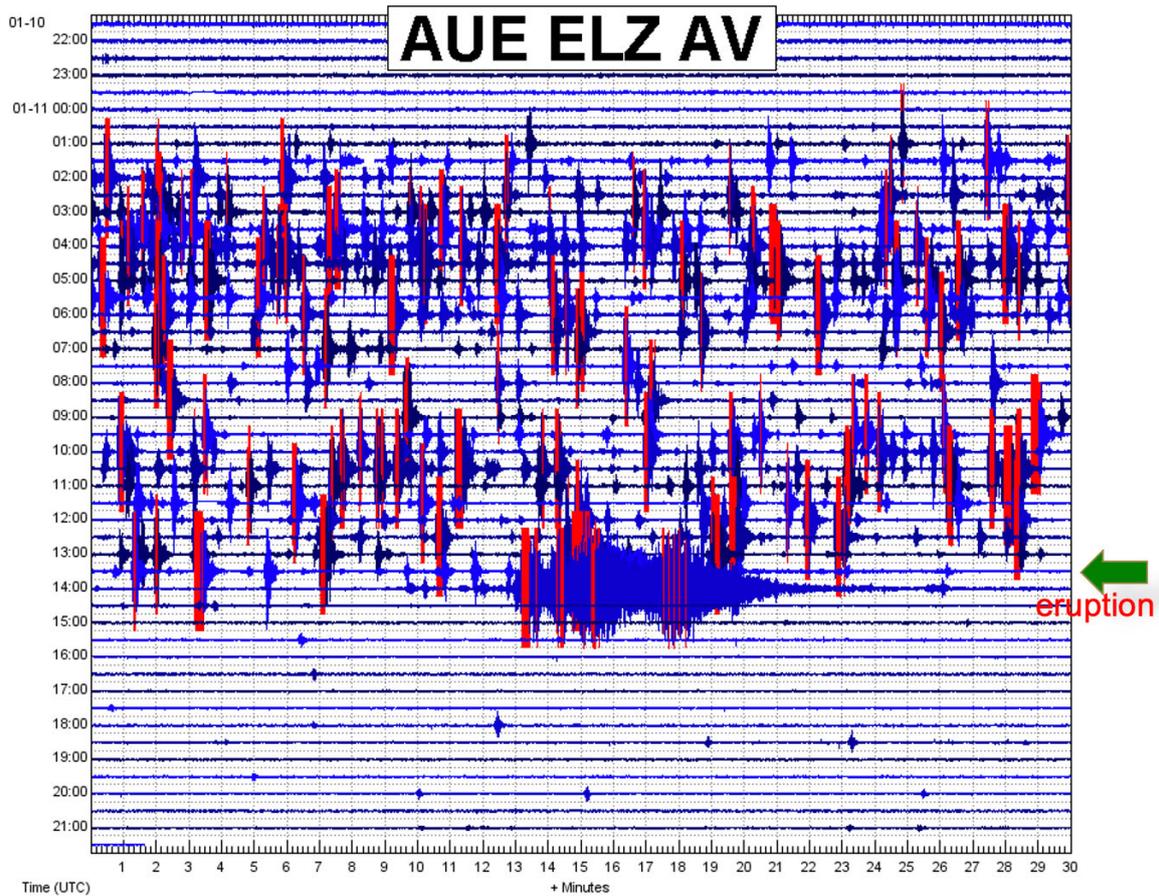


Figure A22. Seismogram of the short swarm on 11 January 2006. The large pulses at 13:44 and 14:12 UTC are the first two explosive eruptions.

Appendix Puyehue-Cordon Caulle (PCC)

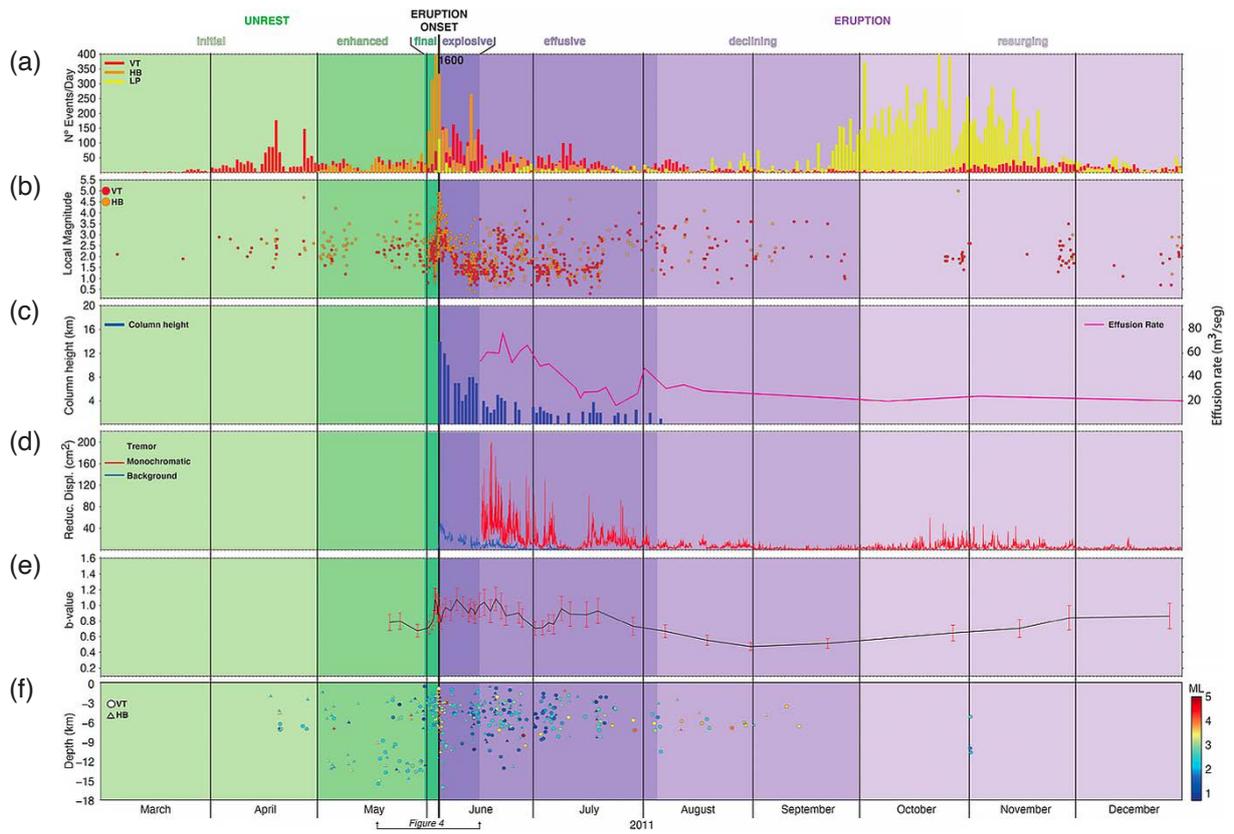


Figure A23. Time series of data for PCC. (a) Number of earthquakes per day. (b) Local magnitude. (c) Ash column height. (d) Tremor reduced displacement. (e) b-values. (f) Earthquake depth. Eruption onset is indicated by vertical line at top. After Basualto et al. (2023).

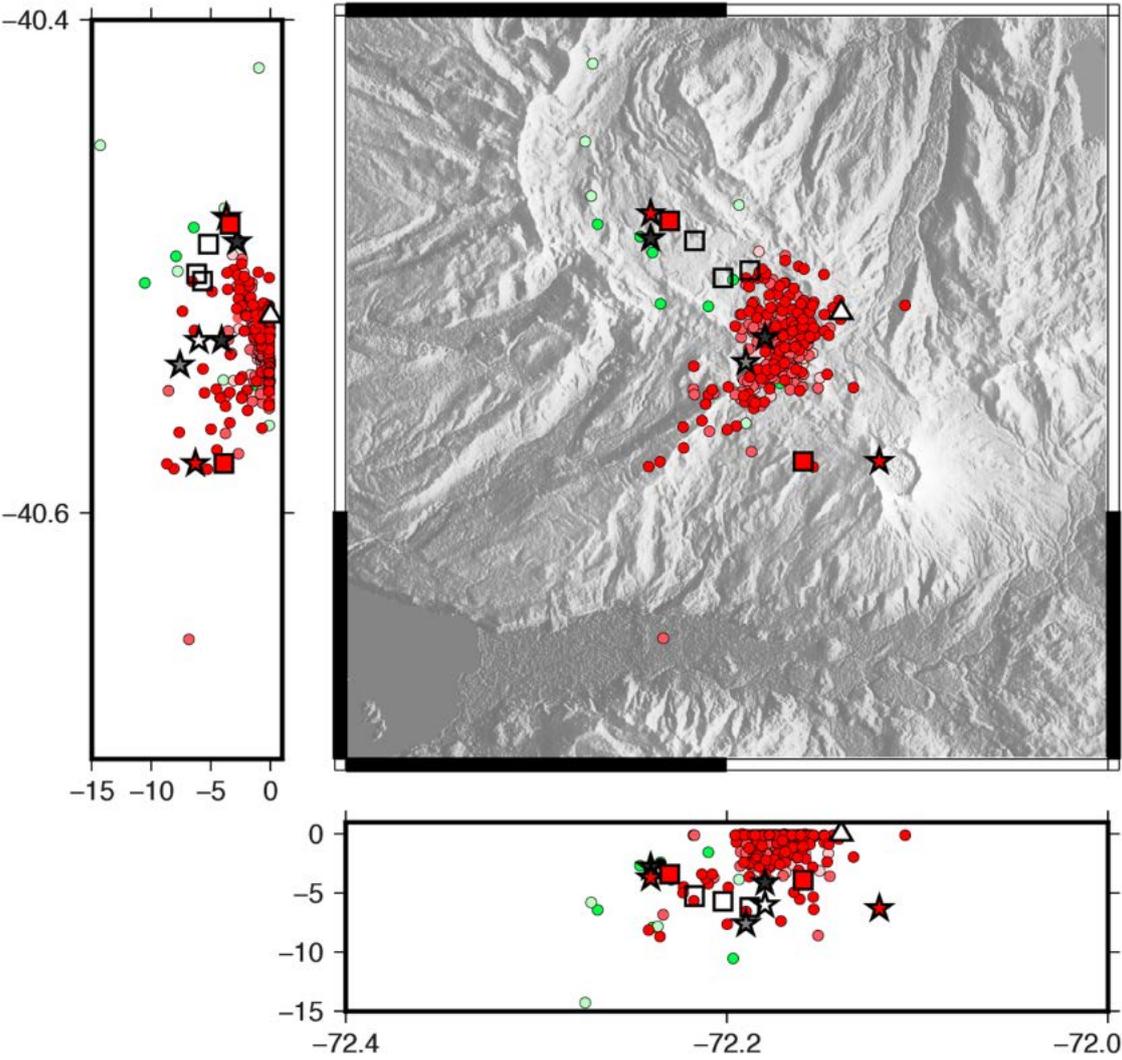


Figure A24. Map and cross section of seismicity for PCC. The time period shown is before eruption onset during the final unrest phase. After Basualto et al. (2023).

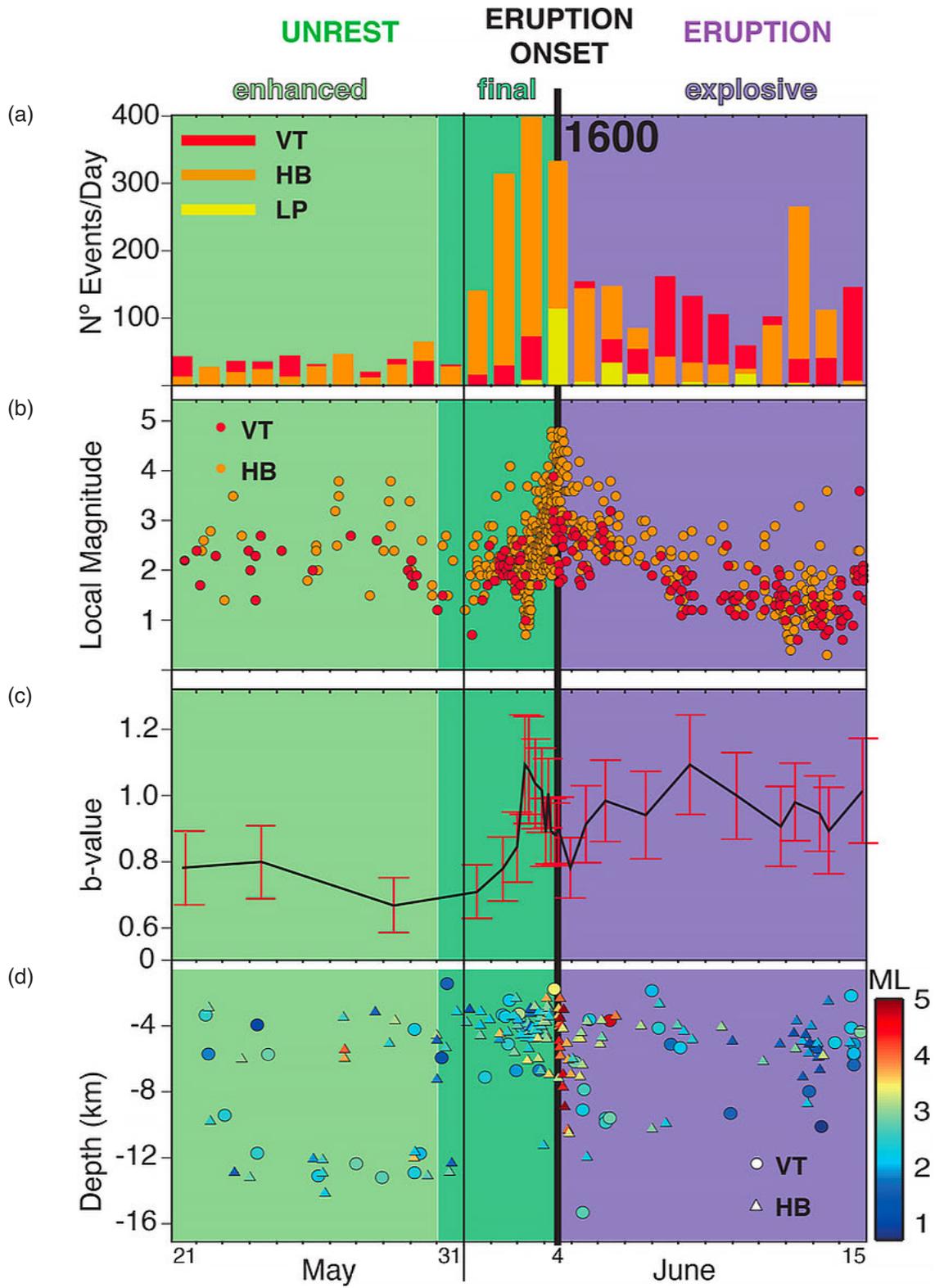


Figure A25. Time series of data for PCC from May-June 2011 showing greater detail for the end of the long swarm and the short swarm. After Basualto et al. (2023).

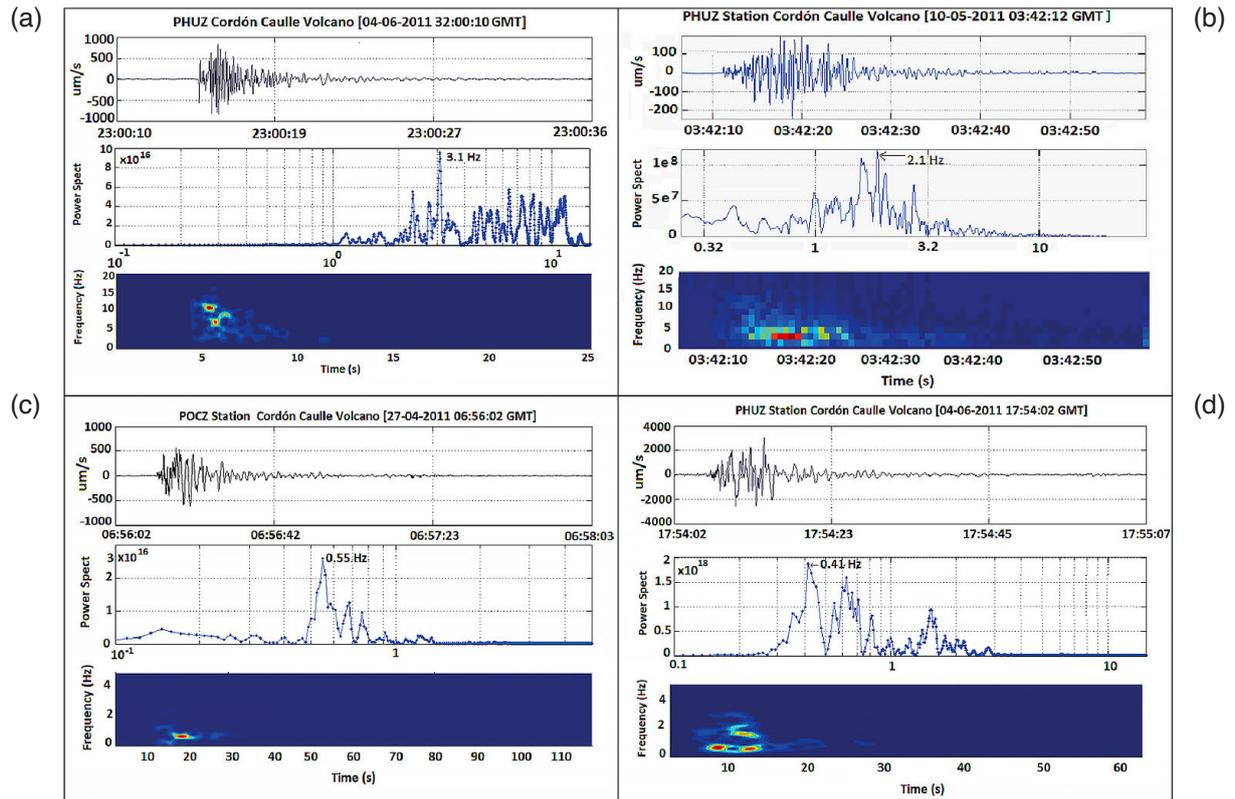


Figure A26. Seismograms and spectra for earthquakes from PCC. (a) Volcano-tectonic (VT) event. (b) Long-period (LP) event. (c) Hybrid (HB) event. (d) Very-Long period (VLP) event. After Basualto et al. (2023).