Data Article

Data on the 1902 Plinian eruption of Santa María volcano, Guatemala.

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ABSTRACT

The study of historic volcanic eruptions is often complicated by the lack of recorded primary data and observations of such events. In the case of large-magnitude historic eruptions, these types of data are important to better understand not only the physical nature of these rare events but also the volcanic and social impacts that follow. In this paper, we compile contemporary data on the Santa María Plinian eruption of 1902, in Guatemala. The data supplement those presented in the original research article [1] but individually provide an interesting and useful compilation of eyewitness testimonies, scientific studies and newspaper reports. We identify key contemporary sources containing quantitative data as well as various qualitative reports that we convert to quantitative measurements through a simple classification scheme. We also compile wind reanalysis data from the time of the eruption to display wind direction and speed with height. Both the data and the description of the methods of data analysis can aid future studies of qualitative (historic, eyewitness) to quantitative data conversion, as well as studies investigating this important eruption.

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Specifications Table

| Subject | Earth and Planetary Sciences |
|---------|-------------------------------|
| Specific subject area | Geology |
| Type of data | Table |
| How data were acquired | Data were acquired through online searches in digitised contemporary newspaper repositories in countries known to have witnessed or been affected by the eruption. |
| Data format | Raw Analyzed |
| Parameters for data collection | Online searches containing keywords related to the event (for example “Santa María”, “volcano”, “Guatemala”) in the range 1902 onwards, with particular focus on 1902–1903. |
| Description of data collection | Online research was the primary method of data collection, involving keyword searches as well as key date searches, focusing on online repositories from countries close to the site of interest (Guatemala, Mexico) as well as countries known to have been impacted by the eruption (Germany, USA, Spain, UK). Sources were compiled electronically and translated before being analysed. |
| Data source location | Newspaper articles and journals were located online as secondary data sources. Details of primary data source locations can be found in Supplementary Material (Table S1). |
| Data accessibility | With the article |
| Related research article | H.C. Berry, K.V. Cashman, C.A. Williams, The 1902 Plinian eruption of Santa María volcano, Guatemala: A new assessment of magnitude and impact using historical sources, J Volcanol Geoth Res. doi:10.1016/j.jvolgeores.2020.107167. |

Value of the Data

- These data are a collection of eyewitness and reported descriptions of the events and impacts of the eruption of Santa María, Guatemala; the second largest volcanic event of the 20th century.
- The data can be used in other projects related to historical volcanology and the analysis and application of contemporary and eyewitness reports in modern research.
- Further work regarding the data in this article could include continued investigation into this significant eruption of the 20th century, its precursors and impacts, as well as studies into different ways of analysing historical qualitative reports.

1. Data Description

Table 1 is a list of key contemporary sources and their specific in-article titles (headings or subheadings) that contained information or reports on the 1902 Santa María eruption. Translations are provided where the original language is not English.

Table 2 is a compilation of all locations in contemporary sources that made reference to having experienced ash fall of less than 10cm from the Santa María eruption; these compose the most distal references of ash fall from the eruption. The table displays reports in their original language as well as translations if the original language was not English. Original languages included Spanish, German and French.

Table 3 is a compilation of all locations in contemporary sources that reference ash fall thicknesses as well as the duration and timing of said ash fall from the Santa María eruption. As in Table 2, we isolated reports of <10cm to obtain the most distal data. Translations are included where the original report language was not English. The start and end time of ash fall is indicated with the respective dates. Many of the locations with thickness and timing data in Table 3 come from a contemporary compilation made by [7].
| Source reference          | Newspaper                          | Date of publication | Title (English)                        | Title (original, if applicable) |
|---------------------------|------------------------------------|---------------------|--------------------------------------|----------------------------------|
| Abbeville Press and Banner, 1902 | Abbeville Press and Banner        | 03–12–1902          | Volcano refugees come                |                                   |
| The Caucasian, 1903       | The Caucasian                      | 15–01–1903          | Severe Earthquake                    | –                                |
| Diario del Hogar, 1902a   | Diario del Hogar                   | 28–10–1902          | There is no volcano in Chiapas       | No hay volcán en Chiapas          |
| Diario del Hogar, 1902b   | Diario del Hogar                   | 29–10–1902          | The unknown clears                   | Se despeja la incógnita          |
| Diario del Hogar, 1902c   | Diario del Hogar                   | 28–11–1902          | Cablegrams: Regagnon Agency          | Cablegramas: Agencia Regagnon     |
| Diario del Hogar, 1902d   | Diario del Hogar                   | 17–12–1902          | The catastrophe in the west          | La catástrofe de occidente        |
| El Abogado Cristiano Ilustrado, 1902 | El Abogado Cristiano Ilustrado   | 06–11–1902          | Newspaper of the week                | Revista de la semana             |
| El Correo Español, 1902a  | El Correo Español                  | 28–10–1902          | There is no volcano in Chiapas       | No hay volcán en Chiapas          |
| El Correo Español, 1902b  | El Correo Español                  | 30–10–1902          | Alarm in Guatemala                   | Alarma en Guatemala              |
| El Correo Español, 1902c  | El Correo Español                  | 04–11–1902          | The ash rain in Guatemala            | La lluvia de cenizas en Guatemala |
| El Correo Español, 1902d  | El Correo Español                  | 06–11–1902          | From Guatemala                       | De Guatemala                      |
| El Correo Español, 1902e  | El Correo Español                  | 20–11–1902          | Terrible situation                   | Terrible situación               |
| El Imparcial, 1902a       | El Imparcial                       | 27–10–1902          | Volcanic eruption in Chiapas         | Erupción de un Volcán en Chiapas  |
| El Imparcial, 1902b       | El Imparcial                       | 28–10–1902          | Where's the volcano?                 | ¿Dónde Está el Volcán?           |
| El País, 1902             | El País                            | 28–10–1902          | The volcanic ash                     | Las cenizas volcánicas           |
| El Popular, 1902a         | El Popular                         | 29–10–1902          | The eruption of the volcano          | La erupción del volcán Santa María |
| El Popular, 1902b         | El Popular                         | 01–11–1902          | The eruption of the volcano          | La erupción del volcán de Santa María |
| El Popular, 1902c         | El Popular                         | 01–11–1902 (p1)     | Echoes from Oaxaca                   | Ecos de Oaxaca                   |
| El Popular, 1902c         | El Popular                         | 01–11–1902 (p4)     |                                          |                                  |
| El Siglo Futuro, 1902     | El Siglo Futuro                    | 19–12–1902          | From Guatemala                       | De Guatemala                      |
| El Siglo Futuro, 1903     | El Siglo Futuro                    | 13–01–1903          | For the honor and glory of the Virgen of Sorrows | Para honra y gloria de la Virgen de las Angustias |
| El Tiempo, 1902a          | El Tiempo                          | 28–10–1902          | Eruption of a volcano in Chiapas     | Erupción de un volcán en Chiapas  |
| El Tiempo, 1902b          | El Tiempo                          | 31–10–1902          | Cable service                        | Servicio cablegrafico            |
| El Tiempo, 1902c          | El Tiempo                          | 16–11–1902          | The eruption in Guatemala            | La erupción en Guatemala         |
| El Tiempo, 1902d          | El Tiempo                          | 21–11–1902          | The eruptions in Guatemala           | Las erupciones en Guatemala       |
| Inter-Mountain Farmer and Ranchman, 1902 | Inter-Mountain Farmer and Ranchman | 18–11–1902          | Terrible rain of ashes:              |                                  |
| La Patria, 1902a          | La Patria                          | 30–10–1902          | Cablegrams                           | Cablegramas                      |
| La Patria, 1902b          | La Patria                          | 01–11–1902          | United States                        | Estados Unidos                   |
| La Patria, 1902c          | La Patria                          | 07–11–1902          | Notes from the Americas              | Notas de las Américas            |
| La Patria, 1902d          | La Patria                          | 15–11–1902          | Chiapas                              |                                  |
| La Patria, 1902e          | La Patria                          | 06–12–1902          | Volcanic eruptions                   | Erupciones Volcánicas            |
| La Voz de México, 1902    | La Voz de México                   | 28–10–1902          | Volcanic eruption in Chiapas         | Erupción volcánica en Chiapas     |
| New York Times, 1902a     | New York Times                     | 31–10–1902          | Conditions in Guatemala              |                                  |
|                          |                                    |                     | (continued on next page)             |                                  |
Table 1 (continued)

| Source reference | Newspaper | Date of publication | Title (English) | Title (original, if applicable) |
|------------------|-----------|---------------------|----------------|---------------------------------|
| New York Times, 1902b | New York Times | 20–11–1902 | Thousands of Indians killed in Guatemala | – |
| New York Times, 1902c | New York Times | 28–11–1902 | Letters from Guatemala | – |
| Nottingham Evening Post, 1902 | Nottingham Evening Post | 29–10–1902 | Eruption of Santa Maria | – |
| The San Francisco Call, 1902a | The San Francisco Call | 13–11–1902 | Over the coffee fincas of Guatemala ash-laden breath of cruel Mount Santa Maria falls, bringing destruction under which republic reels and people stand in dread | – |
| The San Francisco Call, 1902b | The San Francisco Call | 20–11–1902 | Five thousand Guatemalans known to have perished in terrible outburst of volcano's wrath, and two/thirds of the rich coffee belt is turned into a desert waste | – |

Fig. 1 shows a map of the locations referenced in Tables 2 and 3 constructed in ArcMap (an ArcGIS product). The majority of locations were land-based, although two exceptional reports came from steamships crossing the Gulf of Mexico and Pacific Ocean. Due to the unknown exact location of the steamships when these reports were made, their locations were assumed as equidistant from their origin and destination.

Table 4 contains locations referenced in contemporary sources that describe the duration and timing of ash fall from the Santa María eruption. The distance from the volcano is identified as well as translations of original reports where these were not originally in English. In most cases, a date and start time is included in the description (we record the date/s in the table); in some descriptions an end time is also given.

Table 5 includes contemporary reports of phenomena experienced from the Santa María eruption, including reports of tremors, ground shaking and earthquakes (felt reports), noises and explosions (heard reports), smells (smelt reports) and observations of darkness due to ash (darkness reports). These descriptions are compiled from various locations across Central America, from Costa Rica to Mexico. All reports originally not in English have translations provided. The dates of when the phenomena were experienced are stated where known.

Table 6 summarises reports of volcanic hazards and phenomena resulting from the eruption. The locations paired with the hazards are those reported furthest from the volcano to indicate the hazards' maximum reach. Translations are provided where original reports were not in English.

Fig. 2 displays profiles of wind direction and speed from reanalysis wind data obtained from the CERA-20C database within the European centre for Medium-Range Weather Forecasts (ECMWF) website [14]. The data are at 3-hour timesteps and span the time period of maximum eruption intensity, from approximately 18:00 on 24 October 1902 to 09:00 on 25 October 1902. The data are associated with the grid square 15°N, 92°W, to the northwest of the volcano yet where tephra dispersion was concentrated.

Raw data associated with Fig. 2 are located in Supplementary Material (Table S2). These data include U and V wind estimates for the aforementioned location and timesteps, and their calculations to obtain wind direction and speed with height.
Table 2
Contemporary reports containing ash thickness descriptions (with no timing data) from the 1902 Santa María eruption for specific locations in Guatemala and Mexico.

| Location          | Thickness (cm) | Report (English)                                                                 | Report (original, if applicable)                                                      | Source                      |
|-------------------|----------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------|
| 1 Mazatenango     | 1–10           | “...At Mazatenango ... only ashes has fallen and not to such a great depth that it was not possible to save some of the plantation property...” |                                                                                       | New York Times (1902b)      |
| 2 Caballo Blanco  | 5              | “...on the banks of the Ocosito near Caballo Blanco there were only about 5 cm of pumice and ashes...” | “...an den Ufern des Ocosito bei Caballo Blanco lagen nur noch etwa 5 cm Bimssteine und Asche...” | [2]                         |
| 3 Champerico      | 1.3            | “...At Champerico there was about half an inch of ash over the roofs of the houses...” |                                                                                       | Abbeville Press and Banner (1902) |
| 4 Patulul         | 0.1–1          | “...Slight ash falls (less than 1 cm in diameter) were observed ... to the southeast to Patulul...” | “...Leichte Aschenfälle (mit weniger als 1 cm Absatz) wurden ... nach Südosten hin bis Patulul ... beobachtet...” | [3]                         |
| 5 Pochuta*        | 0.1–1          | “...Fine ash fell in ... parts of the Pochuta district...”                       | “...Theihlen des Pochuta-Distrikts fiel feine Asche...”                                | [3]                         |
| 6 Zacualpa        | 0.1–1          | “...Slight ash falls (less than 1 cm in diameter) were observed ... to the ... east to Zacualpa...” | “...Leichte Aschenfälle (mit weniger als 1 cm Absatz) wurden ... beobachtet, nach Osten hin bis Zacualpa...” | [3]                         |
| 7 Chicomuselo     | 2.6            | “...At Comitán, Mr. Tiedemann measured the height of the ash on a roof and obtained the height of 26 mm; I observed the same conditions between La Concordia and Chicomuselo...” |                                                                                       | [4]                         |
| 8 La Concordia    | 2.6            | “...At Comitán, Mr. Tiedemann measured the height of the ash on a roof and obtained the height of 26 mm; I observed the same conditions between La Concordia and Chicomuselo...” | “...en Comitán midió el Sr. Tiedemann la altura de la ceniza en una azotea y obtuvo como resultado la altura de 26 milímetros; las mismas condiciones observó entre la Concordia y Chicomuselo...” | [4]                         |
| 9 Chiapa de Corzo (Grijalva River) | 1–10 | “...It is said that the Grijalva River brought, passing near Chiapa de Corzo, a number of dead fish, one day when the water was laden with ash in suspension...” | “...On dit que la rivière Grijalva apporta en passant près de Chiapa de Corzo, nombre de poissons morts, un jour que les eaux étaient chargés de cendres en suspension...” | [5]                         |
| 10 Juchitán*      | 1–10           | “...Juchitán. October 27 ... The ash rain has stopped which had all the inhabitants of this population very alarmed...” | “...Juchitán. Octubre 27 ... Cesó la lluvia de cenizas que tenía muy alarmados á todos los habitantes de esta población...” | El Imparcial (1902b)        |
| 11 Cintalpa       | 0.1–1          | “...The population of Cintalpa informs that an ash rain is falling...”           | “...De la población de Cintalpa avisan que está cayendo lluvia de cenizas...”             | El Imparcial (1902a)        |
| 12 Tapanatepec    | 0.1–1          | “...According to news, ... in Tapanatepec ... tremors have been felt ... These phenomena come accompanied with ... ash rains...” | “...Según nuestras noticias ... se han sentido temblores en Tapanatepec ... Estos fenómenos se presentan acompañados de ... lluvias de ceniza...” | La Voz de México (1902)     |
| 13 Salto de Agua  | 1–10           | “...In ... Salto de Agua, abundant ash rain has been falling since ... the morning...” | “...En ... Salto de Agua, está cayendo desde ... la mañana, abundante lluvia de ceniza...” | El Tiempo (1902a)          |

(continued on next page)
| Location                               | Thickness (cm) | Report (English)                                                                 | Report (original, if applicable) | Source          |
|----------------------------------------|----------------|---------------------------------------------------------------------------------|-----------------------------------|-----------------|
| Montecristo                             | 0.1–1          | "...In Tuxtla Gutiérrez... ashes are also falling... In Montecristo... similar phenomena have taken place..." | "...En Tuxtla Gutiérrez... también caen cenizas... En Montecristo... se han efectuado fenómenos similares..." | El Tiempo (1902a) |
|                                       |                | "...In various parts of... Tehuantepec... ash rains have been observed..."       | "...En varios puntos de... Tehuantepec... se han observado lluvias de cenizas..." | El Imparcial (1902a) |
| Tehuantepec*                           | 0.1–1          | "...In Tehuantepec a relatively insignificant amount [of ash] fell..."           | "...En Tehuantepec cayó una cantidad relativamente insignificante..." | [4]             |
| Salina Cruz                            | 0.1–1          | "...Salina Cruz, October 27... Today no ash has fallen but the sun is clouded..." | "...Salina Cruz, Octubre 27... Hoy no han caído cenizas pero el sol está nublado..." | El Imparcial (1902b) |
| Yaupevec*                              | 0.1–1          | "...In various parts of... Yaupevec... ash rains have been observed..."          | "...En varios puntos de... Yaupevec... se han observado lluvias de cenizas..." | El Imparcial (1902a) |
| Pochutla*                              | 0.1–1          | "...In various parts of... Pochutla... ash rains have been observed..."           | "...En varios puntos de... Pochutla... se han observado lluvias de cenizas..." | El Imparcial (1902a) |
| Miahuallan*                            | 0.1–1          | "...In various parts of... Miahuallan... ash rains have been observed..."         | "...En varios puntos de... Miahuallan... se han observado lluvias de cenizas..." | El Imparcial (1902a) |
| Jaltipan                               | 0.1–1**        | "...From Jaltipan... they telegraph that an abundant ash rain has fallen there..." | "...De Jaltipan... telegrafían que ha caído allí abundante lluvia de ceniza..." | El Imparcial (1902b) |
| Tiacolula*                             | 0.1–1          | "...In various parts of... Tiacolula... ash rains have been observed..."          | "...En varios puntos de... Tiacolula... se han observado lluvias de cenizas..." | El Imparcial (1902a) |
| Ocotlán*                               | 0.1–1          | "...In various parts of... Ocotlán... ash rains have been observed..."            | "...En varios puntos de... Ocotlán... se han observado lluvias de cenizas..." | El Imparcial (1902a) |
| San Bartolo                            | 0.1–1          | "...in... San Bartolo tremors have been felt... accompanied with... ash rains..."  | "...se han sentido temblores en... San Bartolo... acompañados de... lluvias de ceniza..." | La Voz de México (1902) |
| Juquila*                               | 0.1–1**        | "...Juquila, October 26th... Today dawned raining thick ash which continues..."    | "...Juquila, Octubre 26... Hoy amaneció lloviendo ceniza gruesa y continua..." | El Imparcial (1902a) |
| Ometepec                               | 0.1–1          | "...Ometepec, October 27... For three days a light ash rain has fallen... The roofs are lined with it..." | "...Ometepec, Octubre 27...Hace tres días que cae... una ligera lluvia de cenizas. Los tejados están tapizados de ella..." | El Imparcial (1902b) |
| Acapulco                               | 0.1–1          | "...Slight ash falls (less than 1 cm in diameter) were observed... west to Acapulco..." | "...Leichte Aschenfälle (mit weniger als 1 cm Absatz) wurden... beobachtet... westwärts bis Acapulco..." | [3]             |
| Mérida                                  | 0.1–1          | "...lighter ashes reached as far as... Mérida..."                               |                                 | [6]             |
| Colima                                 | 0.1–1          | "...Slight ash falls (less than 1 cm in diameter) were observed... west to... Colima..." | "...Leichte Aschenfälle (mit weniger als 1 cm Absatz) wurden... beobachtet... westwärts bis Colima..." | [3]             |
| Luxor steamship (San Benito → San Francisco) | 0.1–1**       | "...a precipitation of no less than eight inches on the deck of pumice ashes as fine as flour..." |                                 | Inter-Mountain Farmer and Ranchman (1902) |
| Vigilancia steamship (Progreso → Veracruz) | 0.1–1          | "...The "Vigilancia"... received ash rain on the trip from Progreso to Veracruz..." | "...Die "Vigilancia"... bekam noch Aschenregen auf der Fahrt von Progreso nach Veracruz..." | [7]             |

* Area/region. Data points are placed at the closest point to the volcano within that area (Fig. 1).
** Classified as a lower interval than is suggested by report description due to distance or the surrounding data points.
Table 3
Contemporary reports containing ash thickness descriptions with timing data from the Santa María 1902 eruption for specific locations in Guatemala and Mexico.

| Location          | Thickness (cm) | Ash fall start time | Ash fall end time | Report (English)          | Report (original, if applicable)                                      | Source                  |
|-------------------|----------------|---------------------|-------------------|---------------------------|------------------------------------------------------------------------|-------------------------|
| Comitán           | 3              | 01:00 (25th)        | 09:00 (27th)      | Data table p.86–87        | “…significant and thick ash began to fall…”                           | El Tiempo (1902a)       |
| Ociosoing         | 1              | 06:00 (25th)        | 06:00 (27th)      | Data table p.86–87        | “…empezó á caer una menuda y tupida lluvia de ceniza…”                | El Imparcial (1902b)    |
| San Cristóbal    | 1–10           | 08:00 (25th)        | 16:00 (26th)      | Data table p.86–87        | “…ashes started to fall last night. Today it is much more dense…”      |                         |
| Las Casas         | 1              | 18:00 (25th)        | 18:00 (26th)      | Data table p.86–87        | “…en Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Tonalá            | 2              | 15:30 (25th)        | 15:30 (26th)      | Data table p.86–87        | “…las cenizas continúan cayendo. Todo presenta aspecto como si hubiera caído nevada…” | El Tiempo (1902a)       |
| Palenque          | 1              | 06:00 (25th)        | 17:00 (27th)      | Data table p.86–87        | “…las cenizas continúan cayendo. Todo presenta aspecto como si hubiera caído nevada…” | El Imparcial (1902a)    |
| Macuspana         | 0.1–1          | 07:00 (25th)        | -                 | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Balancán          | 0.1–1          | 05:00 (25th)        | 15:00 (27th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Catarajá          | 0.25           | 06:00 (25th)        | 18:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Jonuta            | 0.1            | 09:00 (25th)        | 18:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Macuspana         | 1–10           | 12:30 (25th)        | 18:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Tacotalpa         | 0.15           | 12:00 (25th)        | 16:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Teapa             | 0.15           | 07:00 (25th)        | 15:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Jalapa            | 0.1–1          | 12:00 (25th)        | 16:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Huimanguillo      | 0.1–1          | 03:00 (26th)        | 23:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Cárdenas          | 0.2            | 15:00 (26th)        | 15:00 (27th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| San Juan          | 0.5            | 20:00 (25th)        | 11:00 (27th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Bautista Nacajuca | 0.1            | 02:00 (25th)        | 12:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Cunduacán         | 0.2            | 10:00 (26th)        | 21:00 (27th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Comalcalco        | 0.15           | 04:00 (26th)        | 23:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Paraiso           | 0.1–1          | 04:00 (26th)        | 11:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Frontera          | 0.3            | 02:00 (26th)        | 11:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |
| Laguna            | 2.5            | 11:00 (25th)        | 11:00 (26th)      | Data table p.86–87        | “…In Tuxtla Gutiérrez … ashes are also falling … In … Tenosique … similar phenomena have taken place…” |                         |

(continued on next page)
Table 3 (continued)

| Location | Thickness (cm) | Ash fall start time* | Ash fall end time* | Report (English) | Report (original, if applicable) | Source |
|----------|----------------|----------------------|-------------------|------------------|---------------------------------|--------|
| Oaxaca   | 0.5            | 18:00 (25th)         | 03:00 (29th)      | Data table p.86–87 |                                | [7]    |
| Campeche | 0.0001         | 05:00 (26th)         | 11:00 (27th)      | Data table p.86–87 |                                | [7]    |

* All timing data is from [7].

Fig. 1. Map of locations referred to in Tables 2 and 3 divided into three categories: those with reports of ash thickness but no timing data (filled circles; Table 2), those with ash thickness reports from steamship tracks with no timing data (filled squares; Table 2), and those with both thickness and timing data (hollow diamonds; Table 3). Also displayed are the location of Santa María (hollow triangle) and a scale inset of Central America.

2. Experimental Design, Materials and Methods

2.1. Data collection

Research was primarily conducted online via digitised repositories of contemporary newspaper articles as well as general research into published scientific reports from around the time of the eruption (1902–1903) and in subsequent years. Articles that made reference to the eruption were sourced from numerous different countries, including Guatemala, Mexico, the USA, Argentina, Spain, Germany, and the UK. Reports and articles were downloaded or documented, and translated using online translation tools where necessary.
2.2. Data manipulation

Reports and articles were analysed and manipulated in four ways, via translation, location identification, conversion from qualitative descriptions to quantitative estimates, and reliability assignment. All reports were translated using online tools where authors were not familiar with the language. Otherwise, translations were performed first-hand. Analysis of locations mentioned in contemporary reports was performed for those locations that could refer to an area (for example a Mexican state) or a specific location within it (e.g. a city with the same name). In
### Table 5
Contemporary observations of the 1902 Santa María eruption: reports of phenomena felt, heard, smelt and observations of darkness.

| Location                  | Report (English)                                                                 | Report (original, if applicable) | Date *“-”* denotes unknown | Source                          |
|---------------------------|----------------------------------------------------------------------------------|----------------------------------|-----------------------------|---------------------------------|
|                           | Felt                                                                             |                                  |                              |                                 |
| Chiapas                   | "...A series of uninterrupted tremors and detonations..."                        | "...una serie no interrumpida de tremores y detonaciones..." | –                            | El Abogado Cristiano Ilustrado (1902) |
| Nicaragua, El Salvador & | "...strong ground shaking in Nicaragua, Salvador, and Costa Rica..."             | "...fuertes sacudimientos de tierra en Nicaragua, Salvador y Costa Rica..." | 26/10/1902                   | El Correo Español (1902a)       |
| Costa Rica City           | "...underground noises and tremors began on the eve of the eruption..."          | "...los ruidos subterráneos y los temblores comenzaron la víspera de la erupción..." | 31/10/1902                   | El Correo Español (1902d)       |
| Guatemala City            | "...The ground, since the moment the eruption began, didn't stop trembling for fifteen days around Champerico..." |                                  | –                            | El Correo Español (1902e)       |
| San Cristobal             | "...In total there have been 45 tremors..."                                     | "...Por total ha habido 45 temblores..." | 26/10/1902                   | Diario del Hogar (1902b)        |
| Champerico                | "The tremors were very frequent..."                                             | "...Los temblores eran muy frecuentes..." | 17/11/1902                   | Diario del Hogar (1902c)        |
| Unspecified               | "...Oscillatory ground movements happened, almost without interruption..."      | "...se sucedían los movimientos oscilatorios del terreno, casi sin interrupción..." | 24–                          | Diario del Hogar (1902d)        |
| San Juan Bautista Oaxaca  | "...No tremors have been felt..."                                               | "...No se han sentido temblores..." | 24/10/1902                   | El Imparcial (1902b)            |
|                           | "Seismic movements with short intervals have been observed in the districts of Tehuantepec, Pochutla, Juquila, Yautepac, Miahuatlan, Ocotlan and Tlacolula..." |                                  | 26/10/1902                   | El Imparcial (1902a)            |
| Acapulco                  | "...Today at [illegible printed number] a.m. there was a strong tremor. Duration, ten seconds. At 7 a.m. it was repeated, but lightly..." | "...Hoy á las ... a.m. hubo un fuerte temblor trepidatorio. Duración, diez segundos. A las siete repitió, pero ligero..." | 26/10/1902                   | El Imparcial (1902a)            |
| San Marcos, Guerrero      | "...at 3 am there was an oscillatory tremor..."                                 | "...dú las 3 h. a. m. hubo un temblor oscilatorio..." | 27/10/1902                   | El País (1902)                  |
| San Cristobal Las Casas, | "...Reports have been received of a terrible earthquake at 10 am today that completely destroyed San Cristobal Las Casas, Tehuantepec and other towns. Until now, nine in the evening, there are no official reports that confirm this..." |                                  | –                            | El Popular (1902a)             |
| Tehuantepec               | "...The enormous force of the earthquakes have deviated the course of the River Naranjo, which has flooded the municipality of Caballo Blanco and a large expanse of fields/lands, causing the water to rise so much that it’s covered houses, trees and fields; what once were towns and fertile fields are now a huge lake..." | "...la fuerza enorme de los terremotos, ha desviado el curso del caudaloso rio del Naranjo, el cual ha inundado la Municipalidad de Caballo Blanco y una gran extensión de terrenos, subiendo el agua á tal altura, que ha cubierto por completo casas, árboles y sembrados; hallándose ahora convertido en un inmenso lago lo que ántes eran poblaciones y fértiles campiñas..." | –                            | El Popular (1902b)             |
| Caballo Blanco and        | "...In the last days frequent tremors have caused various damage..."            | "...ha habido en los últimos días frecuentes temblores que han causado varias averías..." | 27/10/1902                   | El Popular (1902c)             |
| surrounding               | "...News is received from Chiapas of terrifying seismic phenomena that have occurred there..." | "...De Chiapas se están recibiendo noticias aterradoras sobre fenómenos sísmicos que han ocurrido allí..." | 25/10/1902                   | El Tiempo (1902a)              |

(continued on next page)
| Location                        | Report (English)                                                                                                                                                                                                                                                                                                                                                     | Report (original, if applicable)                                                                                                                                                                                                                   | Date “.”-” denotes unknown | Source                      |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-----------------------------|
| Oaxaca                         | “...In various points of the districts of Tehuantepec, Pochutla, Juquila, Yautpep, Miahuatlán, Ocotlán and Tlacolula, seismic movements with very short intervals observed...”                                                                                                                                                                                                  | “...En varios puntos de los Distritos de Tehuantepec, Pochutla, Juquila, Yautpep, Miahuatlán, Ocotlán y Tlacolula, se han observado movimientos seísmicos con intervalos muy cortos...”                                                                                                                                                     | 26/10/1902               | El Tiempo (1902a)           |
| Unspecified                    | “...the ground, from the moment the eruption began, didn’t stop moving in 15 days...”                                                                                                                                                                                                                                                                                | “...La tierra, desde el momento de erupción, no cesó de temblar en 15 días...”                                                                                                                                                                        | –                         | El Tiempo (1902d)           |
| Guatemala, specific location   | “...At the time of the eruption, horrifying tremors were felt here; the animals couldn’t walk and the people had to search for some source of support as the [ground] movements were terribly strong...”                                                                                                                                                                                   | “...en el momento de la erupción, temblores espantosos se han sentido aquí: los animales no podían andar y la gente tenía que buscar algún punto de apoyo, pues los movimientos eran terriblemente fuertes...”                                                                                     | –                         | El Tiempo (1902c)           |
| Unspecified                    | “...Various earthquakes have been felt...”                                                                                                                                                                                                                                                                                                                             | “...Hanse sentido varios terremotos...”                                                                                                                                                                                                                                                                        | –                         | La Patria (1902b)           |
| Nicaragua, El Salvador & Costa Rica | “...In all of Nicaragua, Salvador and Costa Rica strong ground shaking has been felt...”                                                                                                                                                                                                                                                                          | “...En toda Nicaragua, Salvador y Costa Rica, se ha resentido fueres sacudimientos de tierra...”                                                                                                                                                                                                              | –                         | La Patria (1902a)           |
| Tapantepec, San Cristóbal      | “...since the 24th tremors have been felt in Tapantepec, San Cristóbal L. C., Comitán, Tuxtla Gutiérrez, Juchitán and San Bartolo...”                                                                                                                                                                                                                                           | “...Desde el día 24 se han sentido temblores en Tapantepec, San Cristóbal L. C., Comitán, Tuxtla Gutiérrez, Juchitán y San Bartolo...”                                                                                                                                 | 24/10/1902               | La Voz de México (1902)     |
| Las Casas, Comitán, Tuxtla     |                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                  |                           |                             |
| Gutiérrez, Juchitán & San Bartolo |                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                  |                           |                             |
| Quezaltenango                  | “...in Quezaltenango ... where the earth tremors don’t cease...”                                                                                                                                                                                                                                                                                                      | “...en Quezaltenango ... no cesando en ella los temblores de tierra...”                                                                                                                                                                                                                                           | –                         | El Siglo Futuro (1902)      |
| Tumbador, Guatemala            | “...There have been frequent earthquakes, and another eruption is reported in the Department of Tumbador...”                                                                                                                                                                                                                                                     | –                                                                                                                                                                                                                                                                                                                 | –                         | New York Times (1902a)      |
| Mazatenango                    | “...The earth was in continual commotion, shaking down buildings and causing much destruction...”                                                                                                                                                                                                                                                                   | –                                                                                                                                                                                                                                                                                                                 | –                         | New York Times (1902b)      |
| Mazatenango                    | “...At Mazatenango, on the south side of the volcano... At that place most of the buildings had been badly damaged, if not completely destroyed, by the fierce earthquakes that accompanied the eruptions of the volcano. When the last word came from Mazatenango, fifteen days after the first eruption, the earth had been in constant trembling...”                                                                                                           | –                                                                                                                                                                                                                                                                                                                 | –                         | New York Times (1902b)      |
| 30 miles north of the volcano  | “...All that night the earth shook in almost constant vibration...”                                                                                                                                                                                                                                                                                                     | “...The most alarming reports of earthquakes, as many as twenty eight in one day, and devastating tidal waves began to be canvassed among the thoroughly alarmed passengers...”                                                                                                                                  | –                         | New York Times (1902b)      |
| Luxor steamship (San Benito – San Francisco) | “...The most alarming reports of earthquakes, as many as twenty eight in one day, and devastating tidal waves began to be canvassed among the thoroughly alarmed passengers...”                                                                                                                                                                                      | –                                                                                                                                                                                                                                                                                                                 | –                         | Inter-Mountain Farmer and Ranchman (1902) |

(continued on next page)
| Location | Report (English)                                                                                                                                                                                                 | Report (original, if applicable) | Date \(\text{\textsuperscript{*}}\) | Source                                                                 |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------------------------------|------------------------------------------------------------------------|
| Unspecified | "...till the day of the eruption–October 24th–shocks were again very frequent, and, as the day in question approached, became almost incessant..."                                                                 | –                               | 24/10/1902                    | El Abogado Cristianillo Ilustrado (1902)                               |
| Unspecified | "...During the day (October 24) a series of earthquakes was felt..."                                                                                                                                                  | –                               | –                             | [10]                                                                    |

**Table 5 (continued)**

| Location | Report (English)                                                                                                                                                                                                 | Report (original, if applicable) | Date \(\text{\textsuperscript{*}}\) | Source                                                                 |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------------------------------|------------------------------------------------------------------------|
| Chiapas  | "...A series of uninterrupted tremors and detonations..."                                                                                                                                                   | "...una serie no interrumpida de temblores y detonaciones..." | –                             | El Abogado Cristianillo Ilustrado (1902)                               |
| Guatemala City | "...News from Guatemala inform that yesterday, since five in the morning, strong underground noises, which seemed like distant artillery discharges, announced a serious seismic disturbance..."                                                                 | "...Noticias de Guatemala hacen saber que ayer, desde las cinco de la mañana, fuertes ruidos subterráneos, que parecían lejanas descargas de artillería, anunciaron una seria perturbación sísmica..." | 29/10/1902                  | El Correo Español (1902b)                                             |
| Guatemala City | "...In Guatemala City, despite being a hundred miles away from Santa María, constant and terrible underground noises can be heard..."                                                                               | "...En la ciudad de Guatemala, no obstante hallarse á cien millas de distancia de Santa María, se oyen constantes y terribles ruidos subterráneos..." | –                             | El Correo Español (1902b)                                             |
| Unspecified | "...Explosions that seem like artillery rounds can be heard..."                                                                                                                                               | "...Se oyen detonaciones que parecen descargas de artillería..." | 26/10/1902                  | El Correo Español (1902a)                                             |
| Motozintla | "...Adding to this terrifying series of sinister circumstances was the effect of the continuous noises that could be heard, like intense thunder in the midst of the darkness that enveloped the entire population, and also that of the bellowing of the livestock..." | "...A este pavoroso conjunto de circunstancias siniestras hubo que agregar el efecto de los ruidos continuos que se escuchaban, como de intensos truenos en medio de las tinieblas que envolvían á toda la población y además el de los bramidos de los ganados..." | 25/10/1902                  | El Correo Español (1902c)                                             |
| Guatemala City (reported from Panama via El Salvador) | "...underground noises and tremors began on the eve of the eruption..."                                                                                                                                       | "...los ruidos subterráneos y los temblores comenzaron la víspera de la erupción..." | 31/10/1902                  | El Correo Español (1902d)                                             |
| Guatemala (reported from Panama via El Salvador) | "...the explosions have lasted for four days and have been heard everywhere in Guatemala..."                                                                                                               | "...Las explosiones han durado cuatro días y se han oído en toda la República..." | 31/10/1902                  | El Correo Español (1902d)                                             |
| Tuxtlá Gutiérrez, Nicaragua, San Salvador and Costa Rica | "...The ash rain and underground noises continue..."                                                                                                                                                          | "...Continúa lluvia ceniza y ruidos subterráneos..." | 28/10/1902                  | Diario del Hogar (1902a)                                              |
| Palenque, Don Juan Mt. | "...Detonations like gunshots can be heard in various parts of Nicaragua, San Salvador and Costa Rica...”                                                                                                                                                  | "...Se oyen detonaciones como de cañonazos en diversos lugares de Nicaragua, San Salvador y Costa Rica..." | 27/10/1902                  | Diario del Hogar (1902b)                                              |
| Mexico City, El Salvador, Honduras | "...These explosions were so terrifyingly thunderous that they were clearly heard, as like artillery rounds, in this capital [Mexico City]; and even in El Salvador and the bordering region of Honduras they were perceived as dull rumblings...”                                                   | "...Tan espantosamente atronadoras fueron dichas detonaciones, que alcanzaron á oírse claramente, como salvas de artillería, en esta capital; y aun en El Salvador y región limítrofe de Honduras fueron percibidas como sordos retumbos...” | 24–25/10/1902                | Diario del Hogar (1902d)                                              |

(continued on next page)
| Location                  | Report (English)                                                                                                                                                                                                 | Report (original, if applicable)                                                                                                                                                                                                 | Date "\-\" denotes unknown | Source                                      |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|--------------------------------------------|
| Unspecified              | "...At the same time as these detonations were heard the horizon became gradually darker in a terrifying way, the surrounding temperature increased so quickly to the point that it felt difficult to breathe..."                                                                                                                                       | "...A ál mismo tiempo que tales detonaciones se escuchaban, el horizonte iba gradualmente oscureciéndose de un modo pavoroso, subía con toda rapidez la temperatura del ambiente hasta hacerse fatigosa la respiración..."                                                                                          | 24–25/10/1902               | Diario del Hogar (1902d)                    |
| Comitán                  | "...Detonations can no longer be heard..."                                                                                                                                                                    | "...Ya no se escuchan detonaciones..."                                                                                                                                                                                                                                                        | 27/10/1902                  | El Imparcial (1902b)                       |
| Tuxtla Gutiérrez         | "...It is understood that a volcano is erupting; but where it is being ignored. Loud underground noises have been heard since yesterday..."                                                                    | "...Se da por hecho que existe un volcán en erupción; pero se ignora dónde está. Desde ayer se oyen fuertes ruidos subterráneos..."                                                                                                                                                                  | 25/10/1902                  | El Imparcial (1902b)                       |
| Managua (Nicaragua)      | "...Detonations can be heard in various parts of Nicaragua, San Salvador and Costa Rica. Nothing has reached here, other than alarm..."                                                                     | "...Se oyen detonaciones como de cañonazos en diversos lugares de Nicaragua, San Salvador y Costa Rica. Hasta aquí no llega nada, si no es la alarma..."                                                                                                                                   | 27/10/1902                  | El Imparcial (1902b)                       |
| Mexican Embassy, Guatemala | "...The volcano Santa María is in eruption. The rumbling can be heard from here..."                                                                                                                          | "...El volcán de Santa María está en erupción. Los retumbos se oyen hasta aquí..."                                                                                                                                                                                                              |                            | El Imparcial (1902b)                       |
| Oaxaca                   | "...Detonations like artillery fire can be heard from here..."                                                                                                                                               | "...se oyen detonaciones como disparos de artillería..."                                                                                                                                                                                                                                        | 26/10/1902                  | El Imparcial (1902a)                       |
| Cintalpa                 | "...The population of Cintalpa inform that ... underground noises can be heard..."                                                                                                                         | "...De la población de Cintalpa avisan que ... se escuchan ruidos subterráneos..."                                                                                                                                                                                                                 | 26/10/1902                  | El Imparcial (1902a)                       |
| San Juan Bautista        | "...underground noises can be heard in this capital [San Juan Bautista] and even in the coastal populations of Comalcalco, Paraiso, amongst others. That isn't the case in Teapa and Pichucalco..."                                                                            | "...se oyen ruidos subterráneos en esta capital y aun en las poblaciones de la costa de Comalcalco, Paraiso demás. No así en Teapa y Pichucalco..."                                                                                                                                               | 26/10/1902                  | El Imparcial (1902a)                       |
| Macuspana                | "...Explosions could be heard strongly since 2 pm..."                                                                                                                                                        | "...Detonaciones desde las 2 p.m. dejaronse oír fuertes..."                                                                                                                                                                                                                                       |                            | El Imparcial (1902a)                       |
| Cruzada                  | "...Many explosions can be heard due to the eruption of Mt. San Juan..."                                                                                                                                       | "...se oyen muchas detonaciones debido a la erupción del cerro de San Juan..."                                                                                                                                                                                                                  |                            | El Imparcial (1902a)                       |
| Juquila                  | "...At 1 am the night before last, we began to hear strong explosions as if from cannonfire, coming from the south. They continued until 3 pm yesterday..."                                                                                                          | "...Anteanoche, á la una, comenzaron a oírse fuertes detonaciones como de cañón, rumbo al Sur. Continuaron hasta las tres de la tarde de ayer..."                                                                                                                                               | 26/10/1902                  | El Imparcial (1902a)                       |
| Tuxtla Gutiérrez         | "...Since the morning of the 25th strong and continuous underground noises have been heard coming from the south. At 3 pm they stopped completely..."                                                                                                                   | "...Desde la madrugada del día 25 se han escuchado fuertes y continuados ruidos subterráneos, por el rumbo del Sur. A las tres de la tarde cesaron del todo..."                                                                                                                                   | 26/10/1902                  | El Imparcial (1902a)                       |
| Comitán                  | "...Explosions have stopped..."                                                                                                                                                                               | "...Acabaronse detonaciones..."                                                                                                                                                                                                                                                                     | 27/10/1902                  | El País (1902)                             |
| Tuxtla Gutiérrez         | "...Underground noises were heard since 3am yesterday, really frequently until midday..."                                                                                                                  | "...Ruidos subterráneos oyeronse desde las 3 a.m. de ayer, muy frecuentes hasta el medio día..."                                                                                                                                                                                                  | 26/10/1902                  | El País (1902)                             |
| Palenque, Salto de Agua | "...strong explosions can be heard as if some volcano were close to erupting..."                                                                                                                                | "...se oyen fuertes detonaciones, como si algún volcán estuviese próximo á haber erupción..."                                                                                                                                                                                                     |                            | El Tiempo (1902a)                         |
| Tuxtla Gutiérrez, San Cristobal Las Casas | "...underground noises can be heard..."                                                                                                                                                                          | "...se oyen ruidos subterráneos..."                                                                                                                                                                                                                                                                     |                            | El Tiempo (1902a)                         |
| Macuspana                | "...In Macuspana strong and frequent explosions can be heard..."                                                                                                                                              | "...En Macuspana oyense fuertes y frecuentes detonaciones..."                                                                                                                                                                                                                                        | 25/10/1902                  | El Tiempo (1902a)                         |
| Location | Report (English) | Report (original, if applicable) | Date “-“ denotes unknown | Source |
|----------|------------------|----------------------------------|--------------------------|--------|
| 150 miles from Santa María | "...The eruption must be huge, as it has been heard 150 miles away from Santa María..." | "...La erupción debe ser tremenda, cuando ha podido oírse a 150 millas de Santa María..." | – | El Tiempo (1902b) |
| San Cristobal Las Casas | "...In the early morning of October 25th, several successive detonations, similar to those produced by artillery discharges, were heard southeast of this town... that followed one after the other and became louder each time..." | "...En la madrugada del día 25 de octubre próximo pasado, se oyeron hacia el Sureste de esta población, varias detonaciones sucesivas, semejantes á las que producen las descargas de artillería... que se sucedían unas tras otras y eran cada vez más estrepitosas..." | – | La Patria (1902d) |
| San Cristobal Las Casas | "...at dawn... the detonations could be heard from time to time..." | "...al despuntar el alba... se oían de tiempo en tiempo las detonaciones..." | – | La Patria (1902d) |
| Guatemala City | "...underground noises have been heard in the Guatemalan capital..." | "...los ruidos subterráneos se han escuchado en la capital de Guatemala..." | – | La Patria (1902b) |
| Unspecified | "...Detonations can be heard that sound like artillery charges..." | "...Se oyen detonaciones que parecen cargas de artillería..." | – | La Patria (1902a) |
| Guatemala City | "...When the underground noises and tremors started, on the eve of the eruption..." | "...Cuando los ruidos subterráneos y los temblores comenzaron, la víspera de la erupción..." | – | La Patria (1902c) |
| Guatemala | "...The explosions have lasted four days and have been heard throughout the Republic..." | "...Las explosiones han durado cuatro días y se han oído en toda la República..." | – | La Patria (1902c) |
| Tuxtla Gutiérrez, Comitán | "...The underground noises in Tuxtla Gutiérrez and Comitán come from the south and cover an area of fifty leagues; they are of such a strong nature that in Tuxtla Gutiérrez the noises from Comitán can be heard; the distance that separates these two cities is about fifty kilometres..." | "...Los ruidos subterráneos en Tuxtla Gutiérrez y Comitán, previenen del Sur, y abarcan una extensión de cincuenta leguas; son de tal naturaleza fuertes que en Tuxtla Gutiérrez se oyen los ruidos de Comitán y la distancia que separa estas dos ciudades, es de cerca de cincuenta kilómetros..." | – | La Voz de México (1902) |
| 20 leagues from the volcano (≈85 km), near Quezaltenango | "...accompanied by horrendous thunder..." | "...acompañados de truenos..." | – | El Siglo Futuro (1903) |
| Guatemala City | "...At 5 a.m. yesterday there were violent detonations which were heard 150 miles away..." | – | – | Nottingham Evening Post (1902) |
| Guatemala City | "...detonations from the eruption were heard in the capital..." | – | – | New York Times (1902a) |
| Quezaltenango | "...The writer reports passing through terrible hardships, and describes the outbreak of the volcano, which started with a sandstorm and broke with terrific crashes of thunder and vivid lightning..." | – | – | New York Times (1902c) |
| Ocos (steamship City of Para) | "...During the night of Nov. 6 a few hours before the City of Para sailed out of the port, loud rumblings of the earth were heard and heavy reports as of distant thunder came from the direction of the volcano..." | – | 06/11/1902 | New York Times (1902b) |
| La Union, near Tapachula | "...At La Union, not far from that place, subterranean noises have been frequently heard..." | – | – | The Caucasian (1903) |

(continued on next page)
| Location                          | Report (English)                                                                 | Report (original, if applicable) | Date “-“ denotes unknown | Source                                           |
|----------------------------------|----------------------------------------------------------------------------------|----------------------------------|--------------------------|-------------------------------------------------|
| Finca La Magnolia (20 miles SE of Santa María) | “...We could hear every once in a while a heavy, dull explosion...” | –                                | --                       | The San Francisco Call (1902b)                   |
| La Libertad, Honduras            | “...Although 150 miles from La Libertad the explosions on Santa María were heard most distinctly and even in Honduras, 200 miles away, the volcano’s artillery made a loud report...” | –                                | --                       | The San Francisco Call (1902a)                   |
| Costa Rica                       | “...So violent were the detonations, that they were clearly audible in Costa Rica, more than 500 miles distant...” | –                                | 24–27/10/1902            | [9]                                             |
| San Salvador, Chiapas, western Honduras | “...terrifying detonations announced the beginning of the volcanic activity... These explosions were heard so far as the capital of El Salvador, over a great part of Chiapas and the western part of Spanish Honduras...” | –                                | 25/10/1902               | [11]                                            |
| Gualan                           | “...explosions like cannon shooting at short distance...”                         | –                                | --                       | [11]                                             |
| San Cristobal Las Casas          | “...The detonations which accompanied the violent eruptions were heard at great distances like the sound of thunder or that of a distant cannon...” | –                                | --                       | [5]                                             |
| Rabinal                          | “...I was awakened by what I considered to be heavy cannonading of firing of bombs... Towards morning the explosions increased in force, and continued all through the day with intervals of from one and ten minutes. Towards evening the explosions has become more loud and more frequent... the noise was intense and the explosions almost continuous...” | –                                | --                       | [6]                                             |
| Guatemala, El Salvador, Southern Mexico and Yucatán, Tehuantepec | “...The 24th of October 1902, at 6.30 in the afternoon, there were suddenly heard all over Guatemala, Salvador, and the southern part of Mexico and Yucatán heavy retumbos, or underground explosions... in Mexico these retumbos were heard as far as Tehuantepec...” | –                                | 24/10/1902               | [6]                                             |
| Zacapa                           | “...Zacapa, 300 km northeast of the volcano... Towards dawn the loudest retumbos were repeated at longer intervals, but between them one could hear an almost constant muffled roar. The retumbos continued at irregular intervals for the next three days...” | –                                | --                       | [12]                                            |
Table 5 (continued)

| Location | Report (English) | Report (original, if applicable) | Date “–” denotes unknown | Source |
|----------|------------------|----------------------------------|--------------------------|--------|
| San Felipe | “...In San Felipe ... For 5 min an increasingly loud sound as heard from blowing off a tremendous steam boiler...” | “...in S. Felipe ... 5 Minuten lang ein immer lauter werdendes Geräusch wie vom Abblasen eines ungeheueren Dampfkessels gehört wurde...” | 24/10/1902 | [3] |
| Cobán | “...from the north of the country, from Coban, I received a telegram from my brother, telling me that there were tremendous detonations there, indicating a volcanic eruption...” | “...erhielt ich aus dem Norden des Landes, aus Coban, ein Telegramm meines Bruders, das mir meldete, dass man dort gewaltige Detonationen vernahme, die auf einen Vulcanausbruch schliessen liessen...” | 24–25/10/1902 | [2] |
| Guatemala City | “...with intrusive power at irregular intervals, now in rapid succession, now at longer intervals, loud bangs, like shots from the heaviest artillery...” | “...mit aufdringlicher Macht in unregelmässigen Zwischenräumen, bald kurz nacheinander, bald in längeren Intervallen, laute Knalle, wie von Schüssen schwerer Artillerie...” | – | [2] |
| Throughout southeastern Central America, excluding Ocos | “...heavy detonations of frightening strength were audible everywhere in southeastern Central America, but in Ocos on the Guatemalan-Mexican border and in some other isolated places were not heard despite the small distance...” | “...die schweren Detonationen mit erschreckender Stärke noch überall im südöstlichen Centralamerika hörbar waren, aber in Ocos an der guatemaltekisch-mexikanischen Grenze und an manchen anderen isolirten Orten trotz der geringen Entfernung nicht mehr vernommen wurden...” | – | [2] |
| Guatemala City (70 mile radius) (reported from Panama via El Salvador) | “...At 70 miles distance [from the volcano] a strong smell of sulfur is being inhaled...” | “...A 70 millas de distancia aspiranse inhalaciones fortísimas de azufre...” | 31/10/1902 | El Correo Español (1902d) |
| Santa María and surroundings | “...The smell of sulfur is unbearable, and they say that in the estates close to Santa María, animals are dying by asphyxiation...” | “...El olor del azufre es insoporable, y dicen que en las haciendas cercanas al Santa María, los animales mueren asfixiados...” | 28/10/1902 | El Tiempo (1902c) |
| Guatemala City, Cobán | “...the sulfur gas smell from the eruption was very impressive; it carried as far as Guatemala City, and Cobán...” | – | – | [10] |
| Chocolá | “...Chocolá, where the leaves of individual plants and the paint on houses have undergone changes due to the chemical action of the gasses...” | “...Chocolá, wo die Blätter einzelner Pflanzen und der Anstrich der Häuser durch die chemische Wirkung der Gase Veränderungen erlitten...” | – | [3] |

Smelt

| Location | Report (English) | Report (original, if applicable) | Date “–” denotes unknown | Source |
|----------|------------------|----------------------------------|--------------------------|--------|

Darkness

| Location | Report (English) | Report (original, if applicable) | Date “–” denotes unknown | Source |
|----------|------------------|----------------------------------|--------------------------|--------|

(continued on next page)
Table 5 (continued)

| Location            | Report (English)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Report (original, if applicable)                                                                                                                                                                                                                                                                                                                                                           | Date "-" denotes unknown | Source                                      |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|--------------------------------------------|
| San Cristobal Las Casas | "...the sky was dark and seemed covered with charged nimbus, so dense that they intercepted the sunlight, and to make the phenomenon that appeared more terrifying, they had us plunged into indecisive darkness..."                                                                                                                                                                                                                                                                                                                                                           | "...el cielo se presentaba obscurecido y parecía cubierto de cargadas nimbus, tan densas que interceptaban la luz del sol, y para que fuese más pavoroso el fenómeno que se presentaba, nos tenían sumidos en una indecisa obscuridad..."                                                                                                                                                              | -                         | La Patria (1902d)                           |
| San Juan Bautista   | "...There is ash rain and the sky is dark..."                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | "...Hay lluvia de cenizas y el cielo está obscuro..."                                                                                                                                                                                                                                                                                                                                       | -                         | El Tiempo (1902a)                          |

Fig. 2. Profiles of wind direction (A) and speed (B) vs. height from reanalysis data. Time steps of 3 h are displayed in the legend covering the peak eruption period from 24 to 02 to 25–10–1902. The volcano’s elevation is indicated as a dashed line (2.7 km). Peak column height is assumed at approximately 34 km [15].

In these cases, reports were documented conservatively as being situated at the location nearest to the volcano within that area. Another phase of analysis was the assignation of quantitative measurements to qualitative reports. We built a classification scheme to allow for the conversion of qualitative descriptions of ash fall to a quantitative thickness range to fit isopach lines, whereby descriptions of light ash fall were sorted into the 0.1–1 cm isopach and any description of significant amounts of ash (e.g. keywords included “dense” and “abundant”) were sorted into the 1–10 cm isopach. Finally, we also ranked accounts by reliability in order to tackle issues commonly related to historic reporting. We classified reliability according to the source of the report, whereby eyewitness testimonies and scientific studies were classified as having high reliability, whilst unknown or unstated sources were ranked as having low reliability [1].
Table 6
Volcanic phenomena reported from the 1902 Santa María eruption.

| Volcanic phenomenon | Location  | Range (km) | Description at maximum range (original, if applicable) | Source |
|---------------------|-----------|------------|--------------------------------------------------------|--------|
| Gullying and erosion | Costa Cuca | 15.0       | "...I now continued my journey to the once flourishing coffee district of the Costa Cuca. Most of the way was completely buried except for a narrow, freshly trodden footpath, which in turn was cut through by numerous deep erosion channels..." | [3]     |
| Lightning/Electrical storms | El Tránsito | 17.1       | "...all the larger trees were hit by lightning and so damaged - split from top to bottom - that the trunks can hardly be used as timber..." | [2]     |
| Ballistics          | Eden      | 18.5       | "...Eden...mention the frequent occurrence of lightning balls, which fell down on 25 and 26 October in the form of fireballs, when striking under with a dull bang exploded and immediately became dark..." | [7]     |
| Lahars              | Caballo Blanco | 44.5     | "...in the headwaters of the rivers almost all vegetation was destroyed and the falling rainwater flowed with great speed to the collecting canals, causing large floods..." | [2]     |
|                     | Champerico | 63.5       | "...the current of lava could clearly be seen descending the volcano and the sea was full of pumice stone and ash..." | Diario del Hogar (1902a) |
|                     | Ocos      | 73.0       | "...for several leagues on each side of the port of Ocos the shore-line has subsided. About one hundred feet all along this coast has sunk down..." | [6]     |
|                     | Cobán     | 154.0      | "...Sulfurous acid was often expelled in great quantities during the first outbursts; however neighbouring areas generally suffered little as clouds of these gases seldom descended to the ground near the crater; often, however, this happened in a greater, even very great distance (Guatemala, Cobán)..." | [7]     |
|                     | Colima    | 1400.0     | "...very small quantities of ashes still reached Acapulco and Colima, almost 1400 km away..." | [7]     |
|                     | Global    | N/A        | "...Pronounced, but less significant anomalies also occurred in 1903 (following Santa Maria, October 1902)..." | –       |
CRediT Author Statement

Hannah C. Berry: Conceptualization; Methodology; Formal analysis; Investigation; Resources; Writing–original draft; Katharine V. Cashman: Supervision; Conceptualization; Validation; Formal analysis; Writing–Reviewing & Editing; Caroline A. Williams: Conceptualization; Resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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Supplementary Materials

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