Understanding basaltic Plinian activity at Masaya caldera, Nicaragua

Emily C Bamber[1*], Fabio Arzilli[1], Margherita Polacci[1], Giuseppe La Spina[1], Maurizio Petrelli[2], Margaret E Hartley[1], Danilo Di Genova[3], Jonathan Fellowes[1], David Chavarría[4], José Armando Saballos[4], Mattia de' Michieli Vitturi[5] and Mike R Burton[1]

[1] Department of Earth and Environmental Sciences, The University of Manchester, UK
[2] Department of Physics and Geology, Università degli Studi di Perugia, Italy
[3] Institute of Non-Metallic Materials, TU Clausthal, Germany
[4] INETER, Managua, Nicaragua
[5] INGV, Pisa, Italy

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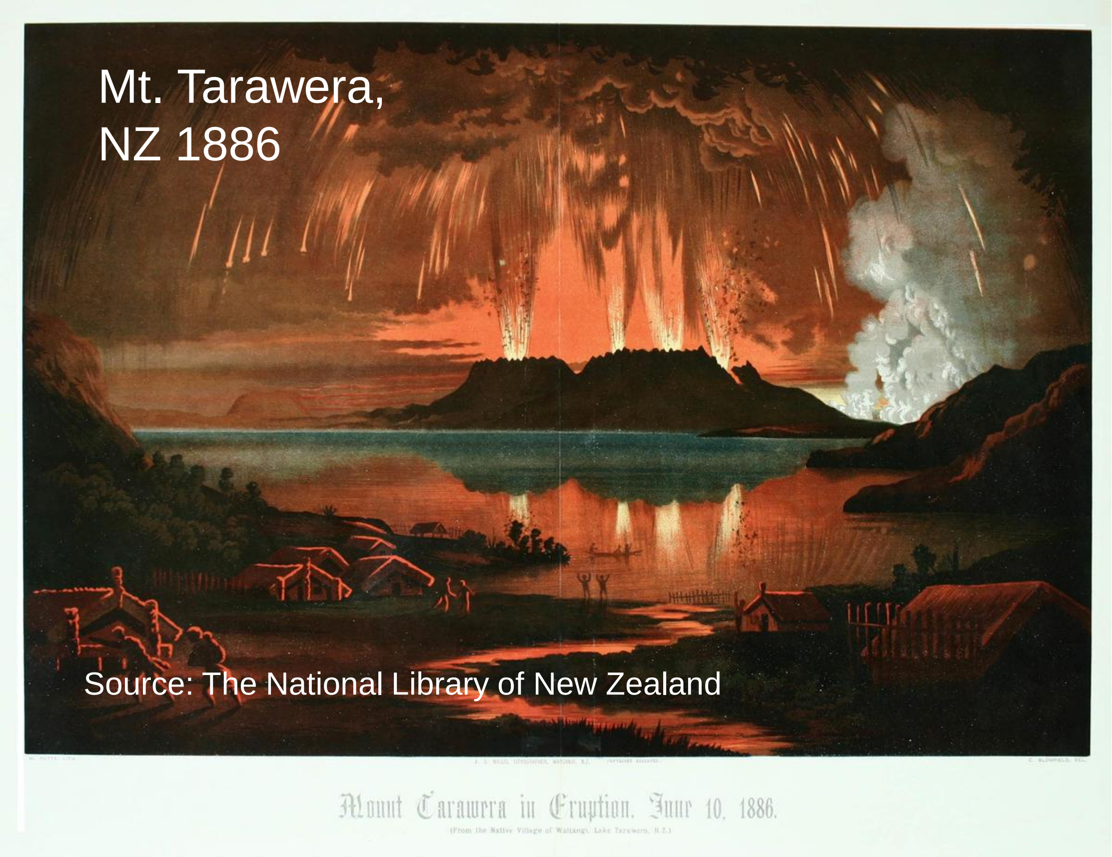
Basaltic Plinian Eruptions



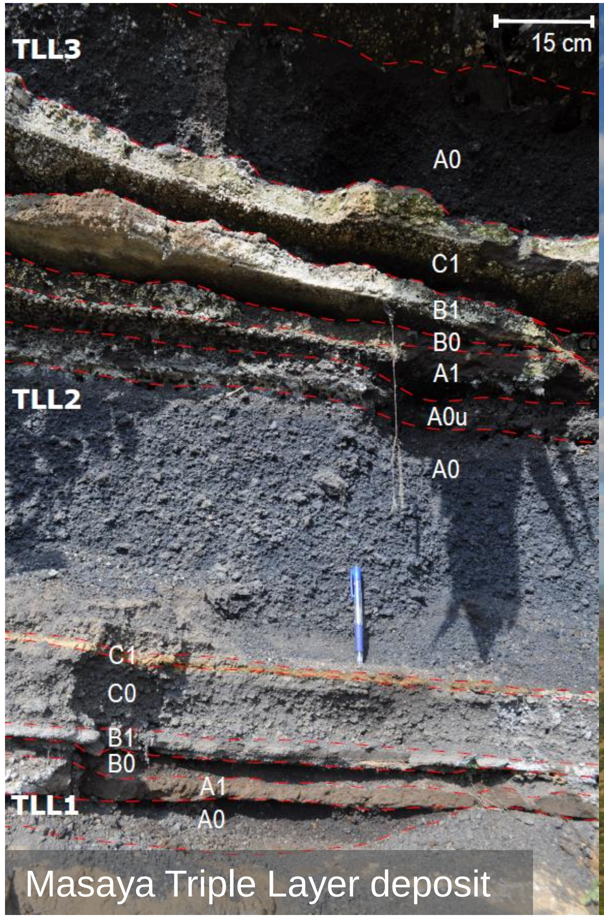
Plinian eruptions are highly explosive end-members of volcanic activity at basaltic systems.

Some examples:

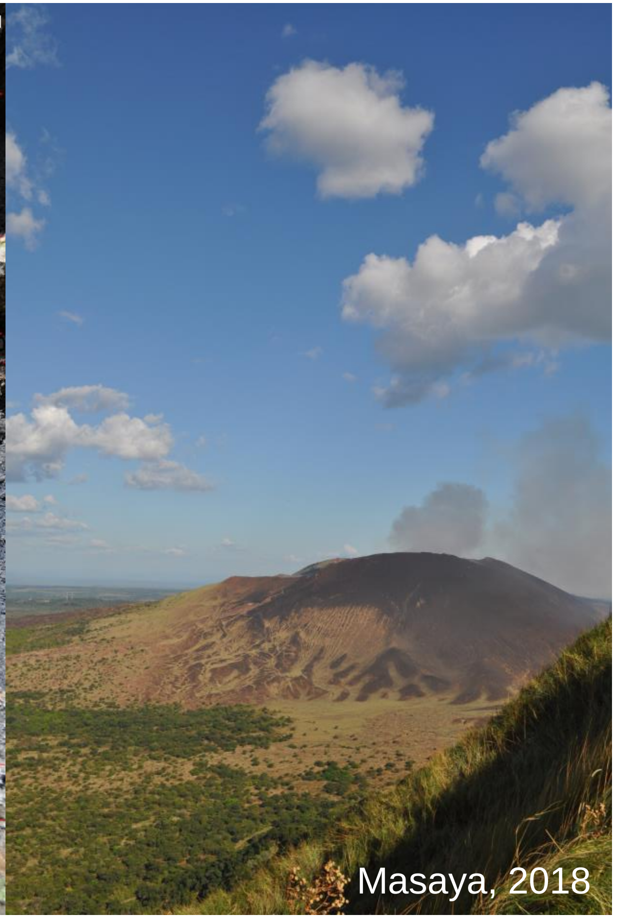
[1] Fontana Lapilli (60 ka), Las Sierras-Masaya complex, Nicaragua
[2] Masaya Triple Layer (2.1 ka), Masaya caldera, Nicaragua
[3] Etna 122 BC, Italy
[4] Tarawera 1886, New Zealand

Understanding the driving mechanisms of highly explosive, Plinian activity at basaltic systems is crucial for hazard assessments. Although rare, there is a high impact produced by basaltic Plinian eruptions.

Masaya Caldera, Nicaragua



Masaya Triple Layer deposit


Masaya, 2018

Bamber et al., 2020, JVGR

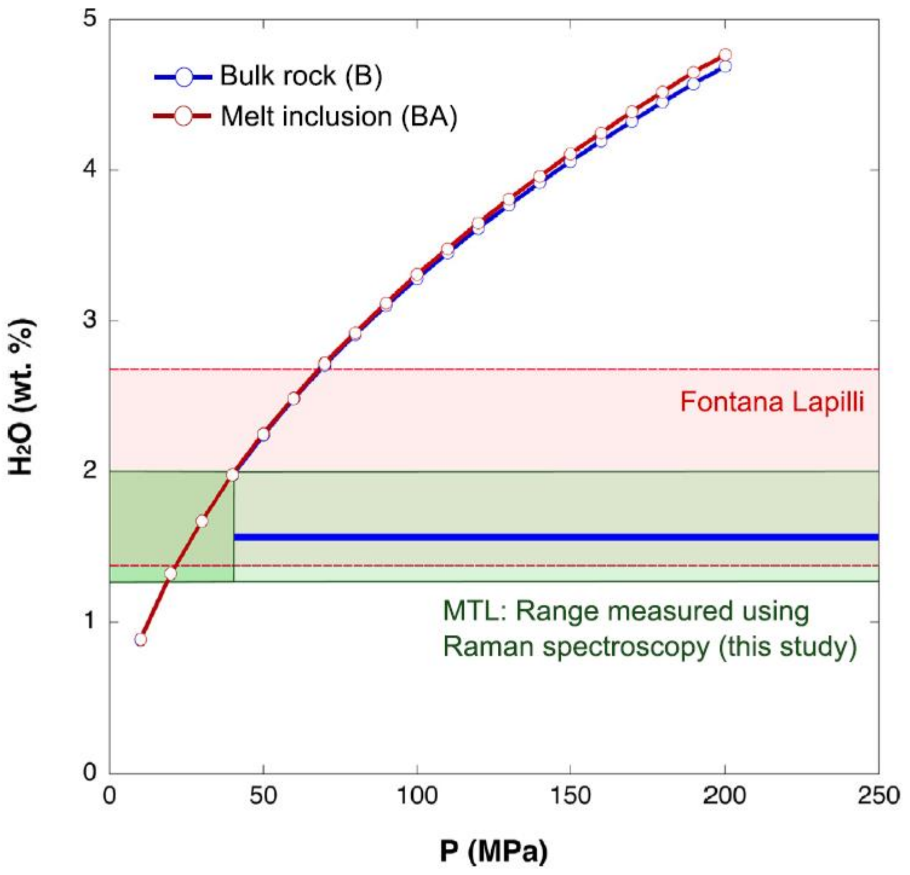
- Masaya caldera is located in western Nicaragua, approximately 25km from the capital Managua
- Frequently active with low explosive activity and persistent degassing
- Last significant eruption of juvenile material was a lava flow in 1772
- However, 3 large Plinian eruptions in the past 6000 years, including the **2.1ka Masaya Triple Layer (MTL) eruption**, depositing tephra over the present day location of Managua
- Proto Masaya system (Las Sierras-Masaya complex) produced the **60ka Fontana Lapilli (FL) eruption**

Method

Study of a volcanic system which shows recurrent Plinian activity allows testing of diverse hypotheses to investigate the driving causes of basaltic Plinian activity.

i. Combine field studies of deposits, petrological examination of samples and numerical modelling of data
ii. Pre-eruptive conditions: Mineral-melt thermometers using EPMA data. Measurements of H_2O concentrations using Raman Spectroscopy. Use of Rhyolite-MELTS to derive pre-eruptive pressure and temperature
iii. Syn-eruptive conditions: Microtextural observations and quantitative textural analysis, combined with a rheological model to investigate magma viscosity
iv. LA-ICP-MS analysis to examine trace element concentrations
v. Numerical simulations using a 1-D multiphase conduit model

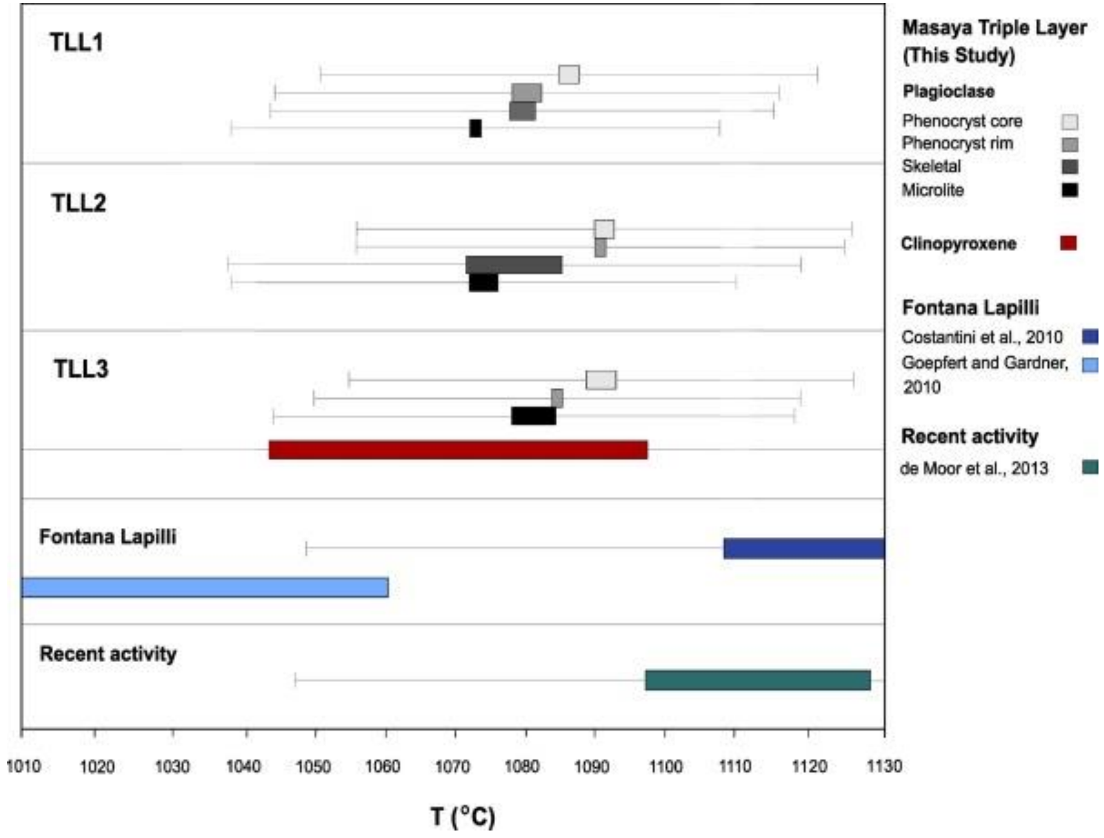
Initial H_2O Concentration



Bamber et al., 2020, JVGR

- Initial H_2O concentration for Masaya Triple Layer eruption (MTL) ranges between 1.3 and 2 wt.%
- The maximum H_2O concentration (2 wt.%) corresponds to water saturation at a pressure of approximately 40 MPa (Moore et al., 1998 model)
- The H_2O range measured for the Masaya Triple Layer eruption overlaps the range measured for the Fontana Lapilli eruption (references [3][7][9]) and the maximum H_2O concentration of activity post-caldera collapse (blue bar [10])

Pre-Eruptive Temperature

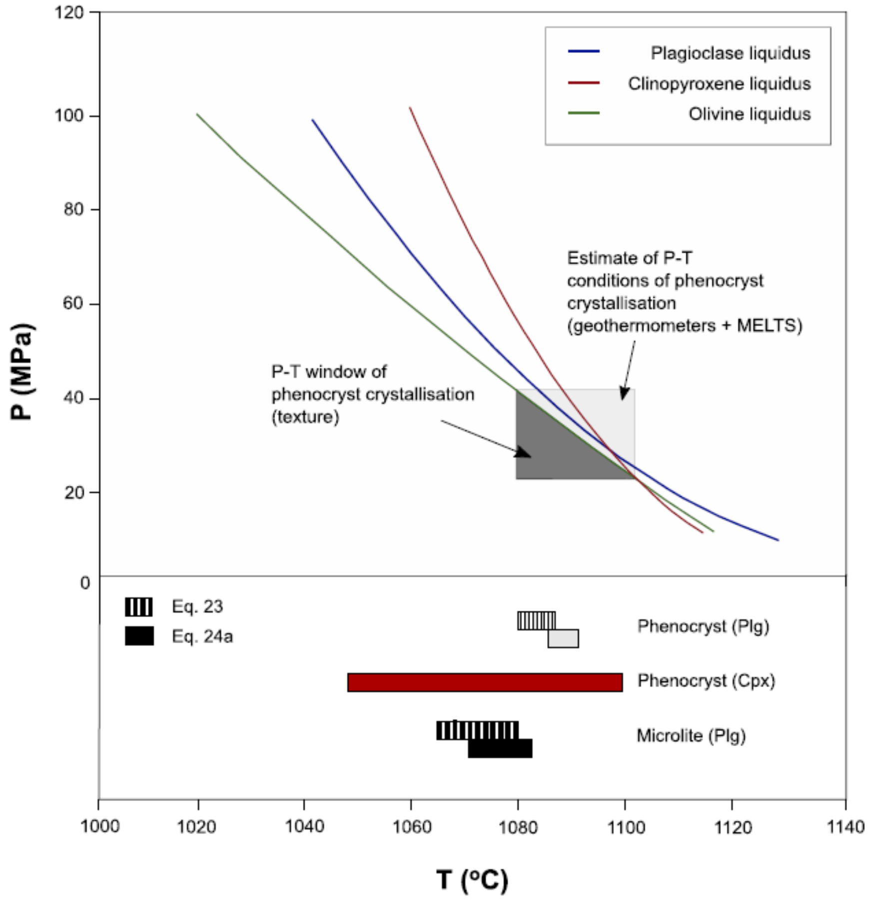


Bamber et al., 2020, JVGR

- Pre-eruptive temperature of plagioclase determined using Putirka (2008) thermometers (eq. 23 and 24a) [6]
- Phenocryst cores crystallise at higher temperatures between 1086 and 1092°C
- More albitic skeletal phenocrysts and microlites crystallise at lower temperatures between 1065 - 1084°C
- Phenocryst cores and microlites crystallised under different conditions
- This temperature range differs from estimates of the pre-eruptive temperature for the Fontana Lapilli eruption and recent, low explosive activity

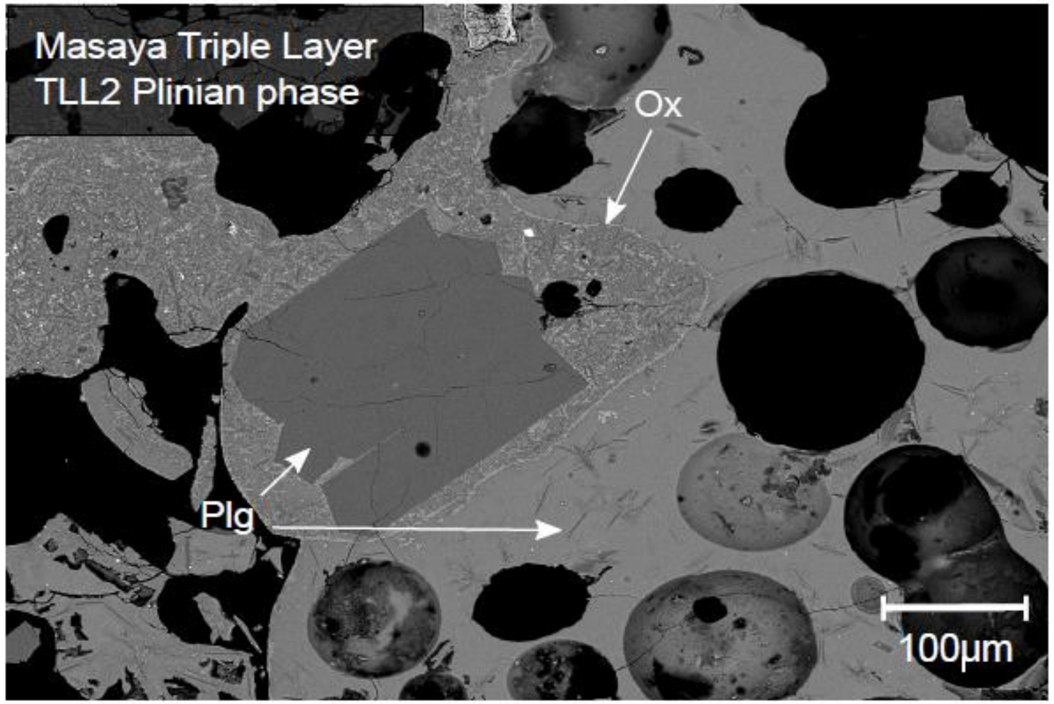
Pre-Eruptive Conditions

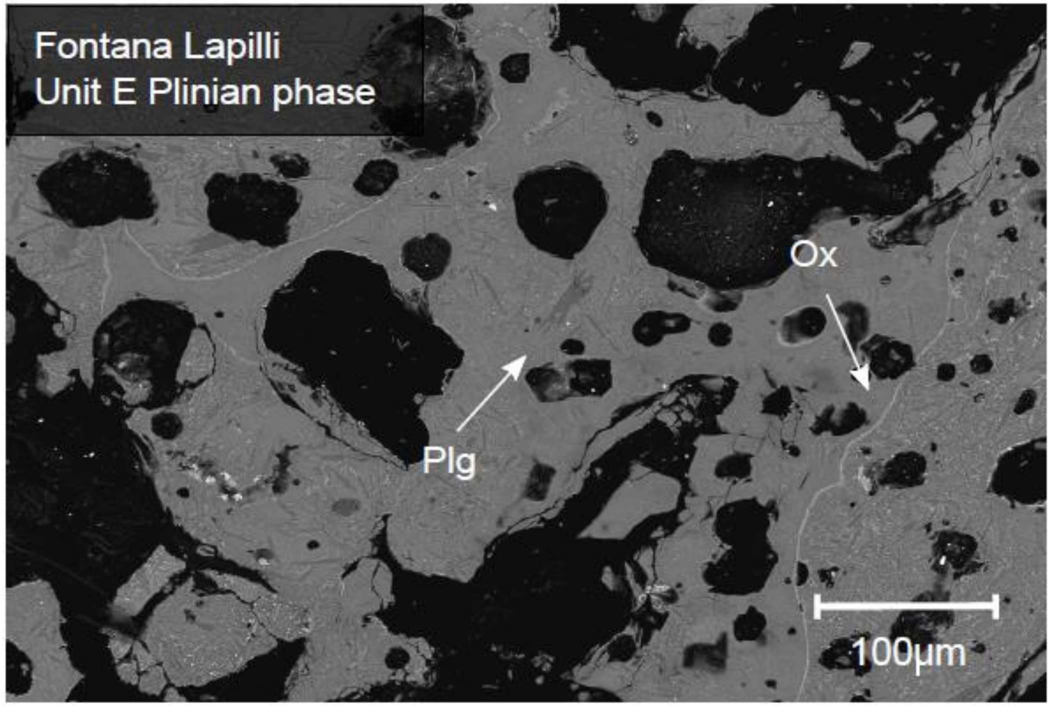
- Rhyolite-MELTS simulations combined with textural observations show magma was last stored before eruption between 1080-1100°C and 21-42 MPa
- Consistent with geophysical investigations of the possible current magma chamber at depth beneath Masaya caldera and theoliitic signature of Masaya erupted products, which crystallised at low pressure and low H_2O (Obermann et al., 2019; Walker et al., 1993)



Bamber et al., 2020, JVGR

Syn-Eruptive Conditions: Textural Evidence





- Samples are highly crystalline, yet exhibit textural heterogeneity. Crystal fraction can vary from 0.2 to 0.5
- Microlite crystallisation promotes magma fragmentation during ascent. Rapid syn-eruptive crystallisation can increase magma viscosity from 10^2 Pa s to 10^6 Pa s, promoting brittle magma fragmentation (Bamber et al., 2020; Arzilli et al., 2019)

Conclusions

- Pre- and syn-eruptive conditions have been constrained for the Masaya Triple Layer Plinian eruption of Masaya caldera.
- Conditions such as low-moderate magmatic storage temperatures, significant, rapid syn-eruptive crystallisation and rapid magma ascent likely promoted magma fragmentation during ascent, resulting in a Plinian eruption.
- These conditions are shared with other examples of basaltic Plinian activity such as the 122 BC eruption of Etna, suggesting basaltic Plinian activity may be promoted by particular physico-chemical conditions.

For more information:

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