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DETERMINING GAS CONTENTS OF MAGMAS THAT PRODUCE SUBMARINE
BASALTIC BALLOONS ERUPTIONS: FOERSTNER 1891 AND SOCORRO 1993

BY

JACOB BALCANOFF

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

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MASTER OF SCIENCE THESIS
OF
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ABSTRACT

Submarine eruptions that produce basaltic balloons are an uncommon eruption style only observed in five cases during historical times. Two well-studied examples occurred at Foerstner volcano in 1891 (Pantelleria, Italy) and at Socorro island, Mexico in 1993. Magmas erupted during these events were crystal-poor, alkali-rich trachybasalts to basanites. Pre-eruption gas contents (CO_2 and H_2O) have been determined using Fournier Transform Infrared Spectroscopy (FTIR) analysis of melt inclusions in olivine and plagioclase phenocrysts. Both eruptions were found to be enriched in carbon dioxide and water relative to other ocean island basaltic compositions. Foerstner inclusions contain 0.17 wt.% to 1.31 wt.% water and 928 ppm to 1834 ppm CO_2 . Socorro inclusions contained higher volatile contents ranging from 0.17 wt.% to 1.09 wt.% water and notably higher CO_2 values from 318 ppm to 3512 ppm. Both eruptions contain sufficient pre-eruption volatiles to produce highly buoyant clasts at the water depth where venting occurred (250-400 m). Individual volatile trends suggest that open system degassing and concentration of CO_2 gas in a foam layer prior to eruption may also have played an important role in generating the excessive vesicularity of the balloon clasts. Calculated balloon rise rates indicate transit times from the seafloor to the surface of up to a few minutes for meter-scale clasts. Positive buoyancy of basaltic balloons in general is likely facilitated by the formation of a quenched crust that isolates large interior gas cavities from cooling and water absorption during ascent through the water column. These results could allow for a clearer understanding in the formation of basaltic balloon eruptions.

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PREFACE

This thesis is in manuscript format, provided by the University of Rhode Island following the guidelines for thesis requirements. This manuscript is prepared for submission to Bulletin of Volcanology, these pages will be listed in the table of contents as the beginnings of the manuscript. Material presented is planned to be presented in poster format at the AGU December 2016 conference.

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**Determining Gas Contents of Magmas that Produce Submarine Basaltic Balloons
Eruptions: Foerstner 1891 and Socorro 1993**

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INTRODUCTION

The production of basaltic balloons is an unusual occurrence associated with shallow submarine eruptions and has only been observed in five cases as of 2016 (Moore et al. 1895; Foerstner 1891; Siebe et al. 1995; Gaspar et al. 1995; Troll et al. 2012). These eruptions produce hollow elliptical clasts often greater than a meter in size with sufficient buoyancy to float on the sea surface where they discharge gas or explode, and then sink back to the seafloor. These products are potential hazards for ships, not only as obstacles, but also because of the potential to explode when depressurized. Balloons can also be used as a paleoenvironmental tool, as they generally indicate a shallow submarine environment. The conditions under which basaltic balloons form are poorly understood due to the rarity of the events and the difficulties to directly observe the eruptive process. One suggested mechanism for their formation is that gas coalesces within sheet-like flows to form bubbles that rise independently through the lava, and then separate from the flow to generate thin-shelled clasts buoyant in seawater (Kueppers et al. 2012). Alternatively, Kelly et al. (2014) proposed that a gas-rich submarine Strombolian eruption could create scoria clasts with gas cavities large enough to be buoyant. An important question regarding balloon formation is whether there is sufficient pre-eruptive gas content to form buoyant clasts or is it necessary to invoke local pre-concentration of volatiles. Simulations of gas coalescence within magma chambers with low viscosity melts have shown that gas can rise independently and coalesce at the roof as a foam layer. Once the foam becomes unstable it can form slugs of varying sizes, which rise through

the conduit driving strombolian and fire fountain style eruptions (Jaupart & Vergnolle 1988). Further studies of primary volatile contents from high-fountaining eruptions and low energy effusive events show little difference in gas abundance, indicating that gas segregation was likely the mechanism to drive the more explosive activity (Taddeucci et al. 2015). However, some studies have shown that differences in eruption style, i.e. effusive versus explosive, can also be due to initial variations in volatile concentrations of primary magmas generated at depth (Sides et al. 2014). Primary volatile contents in pre-erupted magmas are typically determined utilizing silicate melt inclusions trapped within olivine and plagioclase phenocrysts and analyzed by Fournier Transform Infrared Spectroscopy (FTIR) (e.g. Dixon et al. 1995; Metrich & Wallace 2008; Putirka 2008). Gas content in individual balloon clasts can be assessed using a combination of vesicularity, magmatic temperature, and pressure at fragmentation.

Two well-studied examples of balloon eruptions occurred off the islands of Pantelleria, Italy in 1891 and Socorro, Mexico in 1993 (e.g. Kelly et al. 2014; Siebe et al. 1995). No previous studies have assessed the pre-eruptive melt compositions and volatile contents using melt inclusions in balloon samples from these eruptions. Both sites have historical descriptions of the eruptive events, data on depths and configuration of the source vents, and samples for analytical work. In this paper we present the analytical results from melt inclusions and matrix glasses using transmission FTIR and electron microprobe (EMP) from these well-documented events.

These results are used to model the degassing paths of primary melts from Pantelleria and Socorro to evaluate if balloon products could have formed based on critical buoyancy criteria and observed vent depths. Theoretical calculations of balloon rise rates are also presented to evaluate factors that might lead to changes in buoyancy during ascent from the seafloor.

GEOLOGIC SETTINGS

The Island of Pantelleria, Italy is an active volcanic complex containing hot springs, fumaroles, and exhalation mounds releasing steam and sulfurous vapors. The island sits on a northwest by southeast trending channel rift zone (SCRZ) at the northern margin of the African plate (fig. 1). This rift zone formed by lithospheric thinning and has allowed partial melts to penetrate to shallow levels (Civile et al. 2010). The island consists entirely of igneous rocks, mainly peralkaline acidic volcanic products such as pantellerite, enriched in Na, Fe, Cl, and incompatible trace elements (Civetta et al. 1998). Pantelleria's central caldera, Montagna Grande, is built up of trachyte preserved as interbedded tuffs and ignimbrites (Mahood & Hildreth 1986). Located on the northern flank of the island are basaltic lava flows with compositions ranging from olivine alkali-basalts to hawaiites, both with acid signatures (Wright 1980). Pantelleria island has a well-defined shelf closely outlining the perimeter of the island, although in the northwest it extends 2.5 km out at a depth of 50 m below sea level (b.s.l.), possibly a remnant from a previous period of low sea level (Lodolo & Ben-Avraham 2015). Immediately adjacent to the shelf in the northwest is a high concentration of roughly 13 volcanic cones of varying sizes the largest spanning over 1km in diameter (Bosman et al. 2007). To the south, two submarine valleys surrounding the island join and dip towards the Pantelleria Graben (Martorelli et al. 2011).

Socorro Island, Mexico sits at the northern end of Mathematician Ridge running N-S between the E-W trending Clarion and Rivera Fracture Zones (fig. 2). The island

was formed from the abandonment of the Mathematician Ridge at 3.5 Ma, causing crustal weakness and allowing underlying magma to penetrate upwards (Briole et al. 2009). Similar to Pantelleria, the island has fumarole activity giving off sulfur vapors and carbon dioxide (Siebe et al. 1995). 90% of exposed outcrops on the island are trachyte, quartz- trachyte, and aluminum-poor pantellerite with a central pantellerite cone. The remaining 10% consists of sodic olivine-poor basalt, alkali olivine basalt, and trachybasalt found confined to lower elevations on the island (Bryan 1966). Studies conducted on dredged samples by Moore (1970) suggest the area surrounding Socorro is dominated by alkali pillow basalts. A bathymetry study by the Comisión Federal de Electricidad off the western coast of Socorro identified two potential vents located 3.5km and 1.5 km from the coast. These vents are inferred to be the source of the 1993 eruption with peak heights at 230 m and 30 m b.s.l., respectively (Siebe et al. 1995).

SUMMARY OF FOERSTNER AND SOCORRO ERUPTIONS

Foerstner 1891

On October 14th 1891 seismic activity was recorded and a submarine eruption occurred three days later roughly 4 km northwest of Pantelleria with observed basaltic balloons on the sea surface. Foerstner's base lies at 330 m below sea level with a peak height of 250 m below sea level. Once depressurized at the surface large scoria discharged energetic plumes. Occasionally some clasts exploded and were thrown up to 20 m above the ocean surface. The eruption subsided eight days later on October 25th (Butler 1892). The suspected Foerstner vent site was mapped in high resolution using a remotely operated vehicle (ROV) during cruise NA018 of the E/V Nautilus in 2011 (Carey et al. 2011). From this, 13 distinct volcanic facies were identified by Kelly et al. (2014) around the Foerstner vent site. Whole rock analysis of basalt balloons studied by Kelly et al. (2014) from this event generally have a higher TiO₂, FeO₃, and P₂O₅ than other local basalts (Civetta et al. 1998).

Socorro 1993

In late January of 1993, roughly 3 km west of Socorro, a submarine eruption occurred with the formation of basaltic balloons. Elliptical clasts up to 3 meters in size were seen floating between 1 and 15 minutes before losing buoyancy and sinking. Samples were collected by Mexican naval vessels *Holzinger* and *Zapoteco* around Socorro Island from January- July 1993 and the eruption continued intermittently though April 1994. Two months after the February 1993 eruption a bathymetric survey conducted by Comisión Federal de Electricidad and C. Navarro confirmed two

submarine vents off the western coast of Socorro. Vents named A and B are located 4 km and 2 km off the western coast at depths 250 m and 30 m below sea- level respectively. Siebe et al. (1995) conducted electron microprobe analyses of olivines, plagioclases, and glasses and found the samples to have an enriched alkaline signature with high incompatible element contents as well as enriched LREE. Siebe et al. (1995) also noted the importance of CO₂ oversaturation as being the likely cause for the positive buoyancy of the basaltic balloons.

METHODOLOGY

Olivine and plagioclase phenocrysts were extracted from basaltic balloon samples (table 1) using a porcelain jaw crusher, and ground with a mortar and pestle so that the ground rock was proportional to the size of the crystals. Crystals were hand-picked from the crushed sample, examined for melt inclusions in mineral oil, and then cleaned with soap and water. Once dried, crystals containing melt inclusions were placed on a standard one-inch round microscope slide covered in two-piece resin and left to dry under a heating lamp for 30 minutes. The crystals were ground and polished using coarse to fine polishing papers ranging from 240 grits to 0.3 μ m alumina. The samples were then glued to a standard one-inch round microscope slide, ground, and polished on the opposite parallel side. This procedure is delicate and samples can be lost due to the thinness and fragility of melt inclusions when pressure is applied during polishing. Once finished, a high precision micrometer was used to record sample thickness of each individual crystal. Inclusions were analyzed by transmission Fourier transform infrared spectroscopy (FTIR) using a Thermo Scientific Nicolet Continuum FT-IR microscope with Nicolet is50 FT-IR with a resolution setting of 4 cm⁻¹. Five spectra were collected along different positions of exposed melt inclusions with 256 scans per spectra to account for variability. FTIR molecular absorbance values at 3550, 1515, and 1430 were then used with electron microprobe (EMP) analyses to determine weight percentages of volatile components (Dixon et al. 1995 and Luhr 2001). The electron microprobe analyses were conducted at Brown University's Geological Science Department on a Cameca SX-100 electron microprobe, calibrated

using basalt standards BIR, A99 and BCR, gathering 3 scans per melt inclusion, to be later corrected and averaged. Olivine melt inclusions were corrected for post entrapment crystallization (PEC%) using methods from Kelley and Cottrell (2012) to determine the extent of the exchange between the melt inclusion and its corresponding host crystal, assuming the two are in equilibrium at 1200°C with an exchange coefficient, $K_D^{ol/lq}(Fe^{2+}/Mg) = 0.3$, and then adding back 0.1% of the olivine back to the inclusion until equilibrium was reached assuming Fe^{3+} contents remained constant. Iron speciation behavior from Kress & Carmichael (1991) was used to determine the $Fe^{3+}/\Sigma Fe$ using a reduced fugacity of $NNO = -1.6$ from studies on alkaline melts at Erebus (Moussallam et al 2014). Plagioclase hosted melt inclusions were not corrected for post entrapment crystallization. Results of the volatile analyses were used as input parameters for VolatileCalc degassing program (Newman and Lowenstern, 2002) and SolEx degassing software, a 7 component degassing program which corrects for melt compositions (Witham et al, 2012). Results of the volatile analyses were used as input parameters for D-Compress modeling software, developed by Alain Burgisser at the University of Orleans Institute of Earth Sciences, to model the buoyancy of the basaltic balloons

RESULTS

Petrography

Lava balloon sample NA018-018 from the Foerstner 1891 eruption is a plagioclase, olivine, and clinopyroxene-phyric basanite-trachybasalt scoria. It is highly vesicular, displaying porphyritic and hyaloophitic textures (Fig. 3a,b). Some of the internal gas cavities exceed 10 cm in diameter. Plagioclase is the dominant mineral in the scoria, occurring mostly as acicular with some tabular phenocrysts ranging between An₅₅ and An₅₉ (Table 2). Olivines are found mostly as microphenocrysts and microlites ranging from euhedral to subhedral with compositions between Fo₆₉ and Fo₇₂ (Table 2). Less abundant clinopyroxenes typically appear as acicular phenocrysts or microlites, with augitic compositions. Back-scatter electron images (BSE) revealed Fe-Ti oxide microlites throughout the matrix glass, rarely exceeding 250um in length (Fig. 3c,d). The groundmass glass consists of sideromelane, tachylite, or a transitional combination of the two. Tachylitic portions of the sample tend to contain a higher concentration of smaller rounded vesicles whereas sideromelane areas have larger irregular vesicle shapes but with similar vesicle concentrations (Fig. 3).

The Socorro balloon sample collected during the 1993 eruption is a plagioclase and olivine-phyric trachybasalt scoria (Fig. 4a,b). Unlike balloon products of Foerstner, clinopyroxene is absent from the mineral assemblage. Plagioclase phenocrysts are abundant in the sample, occurring mostly as tabular with some acicular forms ranging from An₅₈ to An₆₂ (Table 3). Olivine compositions range between Fo₇₄ and Fo₇₆ and are found as euhedral and subhedral phenocrysts and

microphenocrysts (Table 3). Fe-Ti oxide microlites are much less abundant and smaller, than in the Foerstner samples and are often found attached to, or within olivine phenocrysts. In general, phenocrysts from the Socorro 1993 sample were much larger in size compared to phenocrysts from the Foerstner sample. Similar to the Foerstner balloon, the Socorro matrix glass consists of sideromelane and tachylite (Fig. 4c,d). Both tachylite and sideromelane are highly vesicular, containing small rounded vesicles which become more irregular with increasing size.

Major Element Geochemistry

Matrix glass compositions from the Foerstner 1891 sample are trachybasaltic and relatively uniform in composition (Fig. 5a, Table 4). In general, they are more evolved than the bulk rock compositions reported by Kelly et al. (2014) for a larger suite of samples from the eruption that encompass a range of SiO₂ contents from 42.8 to 46.3%. Olivine-hosted melt inclusions showed relatively low post entrapment crystallization (PEC) between 1.6% and 2.5%, with the exception of NA018-OLV5 whose PEC% was up to 10.4%. Melt inclusions trapped in plagioclase and olivine display a much wider range of compositions that are typically more primitive than the surrounding matrix glass, but with some overlap (Fig. 5b-e, Tables 5 and 6). The compositional diversity seen in the melt inclusions from the single sample NA018-18 has more overlap with the bulk rock analyses of multiple samples from the eruption (Fig.5b-e), suggesting that the event discharged a range of magmatic compositions and that geochemical variation has been trapped by inclusions during crystallization prior to eruption. Major element trends in the melt inclusions appear to follow predictable

crystallization trends for a basaltic melt and do not appear to be significantly impacted by host crystallization. Variation in calcium and aluminum for plagioclase-hosted melt inclusion compositional trends suggest the presence of post entrapment crystallization which could not be corrected for. The FeO and MgO trends versus SiO₂ of the olivine and plagioclase-hosted inclusions overlap and it's difficult to see how comparable trends could be produced from a starting matrix glass composition if host crystallization of different mineral compositions was the controlling factor (fig. 5b,c). We suggest that sample NA018-18 carried with it crystals that reflect crystallization and mixing from coexisting melts that were evolving as magma ascended and that the matrix glass was the last liquid surrounding the crystal assemblage prior to the 1891 eruption.

Matrix glass compositions of our 1993 Socorro sample are also trachybasaltic and relatively uniform in composition (fig. 6a, table 4). The compositions overlap with previous matrix glass analyses from Siebe et al. (1995) and constitute the more mafic endmember of a small eruption trend that extends from ~48 to 49% SiO₂ (fig. 6a). As with the Foerstner sample, melt inclusion compositions of the Socorro scoria exhibit wider major element variations that overlap to some extent with the matrix glass compositions (fig. 6b-e, tables 7 and 8). There are, however, some deviations in some melt inclusions that may be caused by host crystallization. For example, melt inclusions in plagioclase crystals show divergent trends on a MgO/SiO₂ plot (fig. 6c). Compositions with elevated MgO could be generated if host crystallization of plagioclase took place in some inclusions, driving up the levels of MgO. PEC% values

for Socorro olivine melt inclusions are all <4.8% averaging around 3.2%. Such deviations would be expected if some post-entrapment host crystallization took place.

FTIR

Melt inclusions analyzed with transmission FTIR are highly volatile-enriched from both the 1981 Foerstner and 1993 Socorro eruptions, compared to other magmas of similar composition (fig. 7, table 5-8). Analyzed melt inclusions often contained vapor bubbles, indicating dissolved volatiles were extracted from the glass as the inclusion cooled. This means that the presented volatile results are minimum values.

In general, olivine-hosted melt inclusions yielded higher volatile values compared to plagioclase for each event. This is likely due to olivine phenocrysts forming at greater depths and higher temperatures from the parent magmas. Water contents from olivine melt inclusions in the Foerstner sample range between 0.36 wt.% (± 0.02) and 1.09 wt.% (± 0.13), averaging 0.85 wt.%. Four of these melt inclusions contained abundant carbon dioxide ranging from 928 ppm (± 176.1) to 1864 ppm (± 245.4). Plagioclase-hosted melt inclusions from Foerstner contained a range of 0.17 wt.% (± 0.02) to 1.31 wt.% (± 0.16) water with a lower average of 0.51 wt.%, only one plagioclase sample contained detectable carbon dioxide, measuring 980 ppm (± 179). Matrix glasses contain lower volatile contents than the melt inclusions from both crystal phases, with no detectable carbon dioxide in glasses and water content ranging between 0.15 wt.% (± 0.01) and 0.19 wt.% (± 0.02).

Melt inclusions from Socorro olivines have water contents similar to the Foerstner sample ranging from 0.18 wt.% water (± 0.02) to 1.08 wt.% (± 0.04) with a

lower average of 0.77 wt.% (table 7). Melt inclusions from Socorro also contain significant concentrations of carbon dioxide, 9 melt inclusions within olivine-hosted melt inclusions ranged from 330 ppm (± 86) to 3512 ppm (± 295) and 10 melt inclusions within plagioclase crystals (table 8) ranged from 318 ppm (± 52) to 1518 ppm (± 213.8). To our knowledge these are the highest carbon dioxide values ever directly measured in melt inclusions from oceanic basaltic magmas (fig. 7). Water contents in plagioclase-hosted melt inclusions ranged from 0.17 (± 0.01) to 0.9 wt% (± 0.04) with an average water content of 0.63 wt.%, higher than the average value for melt inclusions from plagioclase phenocrysts in the Foerstner sample. Matrix glasses from Socorro's balloon sample contained no detectable carbon dioxide and water concentrations that ranged between 0.3 wt.% (± 0.03) and 0.46 wt.% (± 0.00).

Eruption Degassing Modeling

Volatile degassing during each of the basaltic balloon eruptions was modeled using the VOLATILECALC and SolEx programs (Newman and Lowenstern, 2002, Witham et al. 2012) with input from the melt inclusion FTIR measurements. Sample NA018-018 OLV2a from the Foerstner 1891 event with 0.96 wt.% H₂O and 1834 ppm CO₂ was chosen as the starting point for this eruption. Although the volatile contents are somewhat variable, open system degassing appears to best fit the trend of the data (fig. 8). The saturation pressure associated with the starting volatile contents for a melt with ~45 wt.% SiO₂ at 1200°C from VOLATILECALC is 1477 bars or approximately 4.4 km crustal depth (fig. 8). This is in agreement with previous studies interpreting Pantelleria's magma chamber to be approximately at 4 km crustal depth (Mattia et al.

2007) SolEx saturation pressure is calculated to be roughly 1700 bars or approximately 5.1 km crustal depth (fig 9), deeper than VOLATILECALC results. These variations are likely due to the differences in volatile solubility algorithms used in the two program.

For the Socorro eruption, FTIR results from sample SOC-OLV2 were chosen as the starting volatile parameters with 0.9 wt.% H₂O and 3512 ppm CO₂. The saturation pressure with these volatile contents and a magma composition of 47.5% SiO₂ at 1200°C in VOLATILECALC is 3977 bars, or approximately 11.9 km crustal depth. This is much deeper than previous interpretations of Socorro's magma chamber at approximately 4.5 km crustal depth (e.g. Paoletti et al. 2016). The majority of the volatile data follow a closed system degassing trend, although with some variability, with results mostly lying between 5% and 20% coexisting vapor (fig.10). This indicates the possibility of high concentrations of vapors present at the time of eruption. An alternative explanation for such high primary volatile contents is that a multistage degassing contributed to enrichment of volatiles during magma ascent. At depth, open system degassing of CO₂ occurred and the gas migrated upwards. In a shallower zone, the CO₂ lost from deeper degassing collects and is re-equilibrated with ponding magma, saturating the melt in volatiles. Spilliarert et al. (2006) proposed a similar mechanism to explain apparent excessive primary gas contents in basaltic magma erupted from Mount Etna. This step-wise degassing can be applied to the Socorro volatile data to yield potential degassing paths that involve secondary enrichment of ascending magma with between 5 and 20% volatiles (fig. 11). The discrepancy between VOLATILECALC saturation depths and source chamber studies

suggests upward migration of CO₂ may have played an important role in concentrating CO₂ prior to eruption.

Degassing results of Socorro samples using the SolEx program vary greatly from results of VOLATILECALC. SolEx starts the calculations at a lower saturation of carbon dioxide (2650 ppm) and does not account for the possibility for any exsolved volatiles in the system. The SolEx open system results more closely resemble a closed system degassing pattern, and do not match well the data at lower volatile concentrations (fig. 12). The inferred saturation pressure of maximum volatile contents calculated with SolEx are >4000 bars equating to roughly 12 km depth below crustal.

DISCUSSION

Conditions of basaltic balloon formation

In order for basaltic balloons to form, parcels of magma at the vent must contain sufficient amounts of exsolved gases to be buoyant relative to seawater. For basaltic magma of density equal to 2.5 g/cm^3 this will occur at a gas volume fraction of $> 60\%$. The degassing program D-compress (Burgisser et al. 2015) was used to evaluate whether the maximum amount of dissolved volatiles in the Foerstner and Socorro magmas was sufficient to produce the critical gas volume fractions at the depths of eruption.

Assuming a maximum volatile content of 1835 ppm CO_2 and 0.96 wt.% H_2O for the Foerstner magma, the calculated gas fraction at 250 meters water depth would be 78%. This is in excess of the minimum gas fraction necessary to produce a buoyant clast. However, the volatile data suggest that the magma experienced open system degassing during its ascent to the surface (fig. 8). Such a degassing path would result in significantly lower gas fractions at the time of eruption. Consequently, it is likely that the Foerstner magma was enriched in volatiles from degassing at depth that staged as a foam layer at shallow levels below the vent. In contrast, the Socorro magma contained significantly higher maximum amounts of dissolved volatiles (3512 ppm CO_2 and 0.9 wt.% H_2O). The calculated gas fraction at 250 meters water depth would be 89%, or greatly in excess of the critical value for buoyancy. Unlike the Foerstner magma, the degassing path for the Socorro magma was better fit by closed system degassing, although it was previously argued that such closed system paths inferred

unrealistically high contents of primary gasses. It is more likely that the degassing paths of the Socorro magma also represent secondary enrichment of volatiles from deeper open system degassing.

Factors Controlling Balloon Ascent

Once a basaltic balloon is formed at the vent it will rise through the water column as long as it is buoyant relative to seawater. Factors that will reduce the buoyancy during ascent include 1) water absorption, 2) cooling and contraction of gas bubbles, and 3) catastrophic bursting of bubbles and clast fragmentation. Allen et al. (2008) studied the behavior of gas-rich pumice from submarine eruptions and emphasized the important role that steam condensation plays in water absorption. Submarine pumice differs from subaerial pumice in that its bubbles are only filled with exsolved steam and carbon dioxide. When the pumice cools by contact with water, entrapped steam will condense and the pumice draws in more water, causing it to lose buoyancy very quickly. Experiments on steam-saturated pumices indicate that absorption of water sufficient to cause negative buoyancy occurred on timescales less than 5 minutes (Allen et al., 2008). Basaltic balloon products are somewhat different than pumice in that their central gas cavities appear to be well-insulated and more isolated, as shown by first-hand observations of their incandescent interiors when they reached the surface (Kelly et al., 2014). This suggests that the majority of cooling and water absorption within balloon products is likely limited to only their outer quenched shell, often less than 3-5 cm thick. Allen et al. (2008) also make note that larger

pumice clasts will often fracture from cooling or pressure changes causing a more rapid absorption of water, and loss of buoyancy significantly faster.

Another important factor in the efficiency of water absorption is the ratio of water to carbon dioxide trapped in the gas bubbles and cavities. Maximum water absorption will take place if the gas bubbles are composed dominantly of steam. As the amount of CO₂ increases, the potential contraction and subsequent water absorption will decrease, as CO₂ will not undergo condensation, but will only decrease in volume as the temperature drops. Degassing calculations for the Foerstner and Socorro magmas under closed system assumptions indicate H₂O/CO₂ molar ratios of between 1:1 and 5:2 at the time of eruption. The relatively high amounts of CO₂ in the samples could help mitigate the amount of water absorption due to steam condensation and may, in fact, be an important factor in the ability of basaltic balloons to retain buoyancy and rise to the surface.

In order to further assess the potential for water absorption during the Foerstner and Socorro eruptions, the rise velocities of potential balloon products were calculated from the following equations:

$$V_T = \sqrt{\{g^*(m_d - m)/0.5/\rho_s/C_D/A\}} \quad 1$$

$$v(t) = V_T * \tanh[g^*(m_d - m)/(m_d + m)*t/V_T] \quad 2$$

where V_T is the terminal velocity of the balloon in cm/s, g is the acceleration due to gravity, m is the mass of the balloon product, m_d is the mass of the water displaced, ρ_s is the density of seawater, C_D is the drag coefficient of a sphere, A is the area of the object, and $v(t)$ is velocity as a function of time t . Velocities were calculated for a range of sphere sizes between 25 and 100 cm radius (fig. 13). The masses of potential

balloons from the Foerstner and Socorro eruptions were selected based on D-Compress modelling results of magma bulk densities (exsolved gas+melt) at the time of eruption at 250 meters water depth. When plotted as a function of time, most balloons were found to reach terminal velocity within 2 seconds of their rise to the surface. Because of this, terminal velocities were used to calculate the amount of time it would take to travel the 250 meters from the vent to the sea surface (fig. 13b). A 25 cm radius balloon from the Socorro eruption would have a terminal rise velocity of 300 cm/s, reaching the surface in 83 seconds. Due to the lower volatile contents, producing melts with a higher bulk density, a Foerstner balloon of equal size would have a terminal velocity of 217cm/s reaching the surface in 115 seconds. A 50 cm radius Socorro balloon has a much higher predicted terminal velocity (425 cm/s), being able to reach the surface in in only 59 seconds. A Foerstner balloon with a 50 cm radius would reach the surface in almost equal time as a Socorro balloon with half the diameter (81 seconds). Many of the balloons observed during the Foerstner and Socorro eruptions were a meter or more in diameter meaning that the majority would reach the sea surface in just over a minute. Such rapid ascents would allow less time for cooling and absorption of water during transit to the surface, but given the high rates documented by Allen et al. (2008) it is likely that water absorption at least within the outer crust would have occurred. Assuming a crust of 5 cm thickness and complete absorption of water, the bulk density of a 1-meter diameter Socorro balloon that started at 260 kg/m^3 would increase to 500 kg/m^3 . This is still quite buoyant relative to seawater and the ascent time would only increase from about 55 to 65 seconds. In

order for this type of balloon to become negatively buoyant, 82% percent of the gas bubbles would need to absorb water.

CONCLUSION

Basaltic balloon samples from submarine eruptions of Foerstner volcano (Italy, 1891) and offshore of Socorro island (Mexico, 1993) are alkali-rich (trachybasalts and basanites) with matrix glasses consisting of highly vesicular sideromelane and tachylite. Pre-eruption volatile contents were determined from FTIR analyses of melt inclusions in olivine and plagioclase from both events. Maximum H₂O and CO₂ contents were 1.31 wt.% and 1834 ppm for the Foerstner eruption and 1.09 wt.% and 3512 ppm for Socorro. The latter CO₂ value is the highest yet recorded in melt inclusions from oceanic volcanic rocks. Even some of the lowest recorded values of carbon dioxide measured are high when compared to other melt inclusion data from oceanic islands such as Hawaii.

The measured volatile contents are sufficient to produce an exsolved gas fraction of >60% at the inferred depths of eruption (~250 meters) and generate clasts that would be positively buoyant if closed system degassing occurred. However, the volatile data arrays for both eruptions suggest that open system degassing was more likely and that secondary enrichment of volatiles took place prior to each eruption. This may have been facilitated by the accumulation of gas-rich zones beneath the vents that were fed by open system degassing of magma as it ascended through the oceanic crust. Though the exact staging mechanism for gas prior to eruption is in question, it is clear that the magmas from these eruptions contain sufficient volatile concentrations to generate clasts that would be buoyant in seawater.

Theoretical calculations of basaltic balloon ascent rates through the water column for meter-scale clasts indicate very rapid rise from the seafloor (250 meters) on the order of a few minutes or less. Condensation of primary steam in the gas cavities of the balloons could potentially reduce their effective buoyancy significantly and therefore gas volume fractions may need to be very high to maintain enough buoyancy to ensure transit to the sea surface. High CO₂ contents may also mitigate the effects of buoyancy loss during balloon ascent as CO₂ will not condense to a liquid phase and cause significant absorption of surrounding seawater. Degassing modeling using measured volatile contents for the Foerstner and Socorro eruptions indicate molar ratios of H₂O/CO₂ at the vent pressures as high as ~1.0.

Based on this study, the formation of basaltic balloons, an unusual submarine eruption style, appears to be favored by the eruption of alkali-rich ocean island basalts with high initial contents of the both H₂O and CO₂. Shallow submarine vents also seem to be essential in balloon formation. All the documented historical balloon eruptions have taken place at depths shallower than 400 meters. Kelly et al. (2014) suggest that hydrostatic pressure beyond 400 m depth is too high to allow for large gas cavities to expand and be preserved. Balloons produced at deeper vents will likely absorb more water in their shell and condense entrapped water within the central cavities, drawing in water from the shell causing them to lose buoyancy before reaching the surface. Some areas this style of eruption may occur, based on high melt inclusion volatile contents and submarine venting sites are, Reunion Volcano, Madagascar, seamounts within the Marianas arc, and the Aeolian islands. Italy.

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Sample ID	Depth (m)	LAT.	LONG.	Ship collected	Description
NA018-018	348	36 50.8675'N	11 53.2157'E	<i>Nautilus</i>	Whole scoria balloon bomb
SOC Balloon	210	18 47.75' N	111 04.4'E	<i>Mystique</i>	Whole floating scoria clast

Table 1: Metadata of basaltic balloon samples collected from the Foerstner 1891 and Socorro 1993 eruptions

NA018 balloon sample							
Crystal ID		NA018_olv1	NA018_olv2	NA018_olv3	NA018_plg1	NA018_plg2	NA018_plg3
<i>Crystal composition</i>							
SiO ₂		37.69 ±0.11	38.00 ±0.15	37.44 ±0.05	53.67 ±0.03	53.28 ±0.08	53.18 ±0.02
TiO ₂		0.11 ±0.03	0.06 ±0.01	0.10 ±0.01	0.15 ±0.03	0.13 ±0.02	0.14 ±0.02
Al ₂ O ₃		0.06 ±0.03	0.00 ±0.00	0.02 ±0.01	29.32 ±0.11	29.45 ±0.17	29.48 ±0.08
FeO*		25.11 ±0.49	24.72 ±0.38	26.68 ±0.17	0.77 ±0.07	0.75 ±0.06	0.76 ±0.05
MnO		0.45 ±0.01	0.43 ±0.01	0.47 ±0.05	0.01 ±0.02	0.00 ±0.01	0.01 ±0.01
MgO		36.34 ±0.62	37.13 ±0.26	35.51 ±0.17	0.13 ±0.04	0.12 ±0.00	0.14 ±0.00
CaO		0.56 ±0.06	0.31 ±0.01	0.34 ±0.00	11.70 ±0.17	11.66 ±0.17	11.93 ±0.23
Na ₂ O		0.02 ±0.02	0.00 ±0.00	0.03 ±0.01	4.67 ±0.29	4.71 ±0.09	4.33 ±0.12
K ₂ O		0.01 ±0.00	0.00 ±0.00	0.00 ±0.00	0.30 ±0.01	0.29 ±0.01	0.28 ±0.01
P ₂ O ₅		0.42 ±0.25	0.18 ±0.01	0.36 ±0.03	0.04 ±0.02	0.04 ±0.02	0.04 ±0.01
SO ₂		0.00 ±0.00	0.02 ±0.01	0.03 ±0.01	0.00 ±0.01	0.02 ±0.01	0.00 ±0.00
Total		100.77 ±0.28	100.83 ±0.01	100.96 ±0.02	100.76 ±0.18	100.46 ±0.34	100.28 ±0.34

Table 2: Electron microprobe results from analysis of minerals from the Pantelleria balloon sample

NA018_plg4	NA018_cpx1	NA018_cpx2	NA018_cpx3	NA018_cpx4
53.90 ±0.69	47.16 ±0.62	46.92 ±0.11	49.20 ±2.45	48.50 ±1.63
0.15 ±0.01	2.74 ±0.15	2.93 ±0.29	1.38 ±0.04	2.18 ±0.67
29.02 ±0.38	5.44 ±0.25	5.68 ±0.38	2.70 ±0.11	4.47 ±1.57
0.77 ±0.06	9.13 ±0.37	8.93 ±0.17	9.04 ±0.47	8.86 ±0.05
0.02 ±0.01	0.17 ±0.05	0.17 ±0.01	0.25 ±0.01	0.17 ±0.04
0.13 ±0.02	13.12 ±0.19	13.14 ±0.21	15.03 ±1.02	13.95 ±1.09
11.31 ±0.33	21.68 ±0.27	20.76 ±0.49	20.45 ±0.86	20.79 ±0.57
4.77 ±0.24	0.50 ±0.05	0.39 ±0.01	0.29 ±0.01	0.39 ±0.13
0.30 ±0.01	0.01 ±0.01	0.00 ±0.00	0.01 ±0.01	0.00 ±0.01
0.04 ±0.03	0.30 ±0.45	0.04 ±0.01	1.43 ±1.93	0.20 ±0.25
0.01 ±0.00	0.01 ±0.01	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
100.41 ±0.29	100.25 ±0.31	98.95 ±1.03	99.76 ±0.04	99.53 ±0.22

Table 2 continued...

Socorro balloon sample							
Crystal ID	SOC_L_olv1	SOC_R_olv1	SOC_L_olv2	SOC_L_olv3	SOC_L_plg1	SOC_L_plg2	
<i>Crystal composition</i>							
SiO ₂	38.16 ±0.31	38.50 ±0.19	38.45 ±0.03	38.66 ±0.12	52.71 ±0.61	52.87 ±0.30	
TiO ₂	0.05 ±0.04	0.06 ±0.03	0.05 ±0.01	0.04 ±0.02	0.15 ±0.01	0.20 ±0.04	
Al ₂ O ₃	0.03 ±0.00	0.03 ±0.02	0.05 ±0.01	0.02 ±0.01	30.05 ±0.36	29.80 ±0.01	
FeO*	22.50 ±0.50	21.53 ±0.39	22.14 ±0.07	21.78 ±0.73	0.76 ±0.06	0.79 ±0.06	
MnO	0.33 ±0.02	0.31 ±0.02	0.38 ±0.01	0.36 ±0.02	0.00 ±0.01	0.01 ±0.01	
MgO	38.89 ±0.30	39.45 ±0.21	39.11 ±0.06	39.59 ±0.60	0.14 ±0.01	0.15 ±0.02	
CaO	0.30 ±0.02	0.26 ±0.04	0.27 ±0.00	0.25 ±0.01	12.45 ±0.46	12.33 ±0.16	
Na ₂ O	0.02 ±0.04	0.01 ±0.01	0.03 ±0.04	0.02 ±0.02	4.26 ±0.33	4.10 ±0.14	
K ₂ O	0.00 ±0.01	0.00 ±0.00	0.01 ±0.01	0.00 ±0.01	0.22 ±0.03	0.24 ±0.01	
P ₂ O ₅	0.09 ±0.02	0.10 ±0.06	0.06 ±0.01	0.12 ±0.08	0.02 ±0.01	0.02 ±0.02	
SO ₂	0.02 ±0.01	0.01 ±0.01	0.02 ±0.02	0.01 ±0.01	0.03 ±0.03	0.01 ±0.01	
Total	100.41 ±0.02	100.27 ±0.12	100.55 ±0.07	100.85 ±0.30	100.80 ±0.22	100.50 ±0.19	

Table 3: Electron microprobe results from analysis of minerals from the Socorro balloon sample

SOC_R_plg1	SOC_R_plg2
53.62 ±0.34	52.51 ±0.10
0.15 ±0.03	0.12 ±0.02
29.35 ±0.25	30.29 ±0.14
0.81 ±0.06	0.71 ±0.06
0.00 ±0.00	0.01 ±0.02
0.15 ±0.03	0.14 ±0.01
11.85 ±0.36	12.73 ±0.14
4.57 ±0.19	4.23 ±0.16
0.27 ±0.01	0.21 ±0.02
0.02 ±0.02	0.03 ±0.01
0.00 ±0.00	0.01 ±0.02
100.79 ±0.24	100.99 ±0.12

Table 3 continued...

Matrix glass							
Glass ID		NA018_1_GL	NA018_2_GL	NA018_3_GL	NA018_4_GL	NA018_5_GL	NA018_6_GL
<i>Glass composition</i>							
SiO ₂		46.73 ±0.19	46.37 ±1.09	46.45 ±0.70	46.72 ±0.12	46.66 ±0.11	46.51 ±0.61
TiO ₂		4.24 ±0.10	4.17 ±0.21	4.12 ±0.50	4.22 ±0.06	4.20 ±0.11	4.33 ±0.15
Al ₂ O ₃		13.05 ±0.18	12.44 ±0.52	11.73 ±0.55	13.06 ±0.04	13.04 ±0.10	12.83 ±0.48
FeO*		13.64 ±0.28	14.03 ±0.65	13.77 ±1.74	13.77 ±0.11	13.61 ±0.15	14.13 ±0.91
MnO		0.28 ±0.01	0.28 ±0.06	0.31 ±0.06	0.24 ±0.04	0.27 ±0.01	0.25 ±0.02
MgO		4.40 ±0.26	4.23 ±0.30	4.01 ±0.20	4.58 ±0.05	4.59 ±0.09	4.67 ±0.27
CaO		9.30 ±0.24	9.62 ±0.94	10.43 ±0.78	9.32 ±0.06	9.34 ±0.07	9.32 ±0.26
Na ₂ O		4.02 ±0.21	3.72 ±0.15	3.74 ±0.35	3.91 ±0.12	3.80 ±0.08	3.88 ±0.22
K ₂ O		1.86 ±0.14	2.11 ±0.18	1.94 ±0.46	1.47 ±0.01	1.48 ±0.02	1.60 ±0.14
P ₂ O ₅		2.09 ±0.04	2.50 ±0.73	2.33 ±0.13	2.06 ±0.03	2.07 ±0.07	2.21 ±0.14
SO ₂		0.24 ±0.03	0.23 ±0.03	0.14 ±0.06	0.21 ±0.04	0.21 ±0.04	0.32 ±0.23
Total		99.84 ±0.21	99.70 ±0.18	98.96 ±2.62	99.56 ±0.22	99.26 ±0.22	100.05 ±0.67
H ₂ O		0.15 ±0.01	0.15 ±0.05	0.19 ±0.02	-	-	-
CO ₂ (ppm)		n.d.	n.d.	n.d.	-	-	-

Table 4: Electron microprobe results from matrix glass of Pantelleria and Socorro balloon samples

	SOCL_1_GL	SOCL_2_GL	SOCL_3_GL	SOCL_1_GL	SOCL_2_GL	SOCL_3_GL	SOCL_1_GL	SOCL_2_GL	SOCL_3_GL		
47.64	±0.38	47.49	±0.08	47.39	±0.15	47.78	±0.24	48.03	±0.42	47.65	±0.64
3.80	±0.05	3.87	±0.08	3.87	±0.15	4.12	±0.19	4.03	±0.13	3.97	±0.10
14.48	±0.35	14.40	±0.05	14.54	±0.05	13.69	±0.50	13.83	±0.63	14.05	±0.38
12.48	±0.46	12.48	±0.11	12.41	±0.14	14.06	±1.39	13.81	±0.87	13.00	±0.51
0.19	±0.02	0.20	±0.03	0.19	±0.01	0.23	±0.03	0.23	±0.05	0.23	±0.04
4.95	±0.39	4.91	±0.06	4.74	±0.05	4.72	±0.34	4.44	±0.52	4.99	±0.17
9.23	±0.08	9.29	±0.07	9.20	±0.07	8.19	±1.01	8.67	±0.53	8.99	±0.18
3.88	±0.13	3.81	±0.26	3.86	±0.11	4.08	±0.26	4.07	±0.35	4.30	±0.12
1.29	±0.02	1.27	±0.02	1.31	±0.04	2.12	±0.40	1.96	±0.33	1.51	±0.24
0.92	±0.03	0.95	±0.05	0.93	±0.06	0.95	±0.02	0.99	±0.05	0.93	±0.05
0.14	±0.04	0.13	±0.02	0.16	±0.04	0.17	±0.04	0.15	±0.03	0.12	±0.02
99.02	±0.37	98.81	±0.37	98.59	±0.29	100.12	±0.31	100.22	±0.49	99.75	±1.05
0.3	±0.03	0.46	±0.00	0.43	±0.02	-	-	-	-	-	-
n.d.	-	n.d.	-	n.d.	-	-	-	-	-	-	-

Table 4 continued..

NA018 balloon sample							
Crystal ID	018_OLV2a	018_OLV2b	018_OLV3	018_OLV5	018_OLV8	018_CPX1	
<i>Glass inclusion</i>							
SiO ₂	44.88 ±0.55	olv2a data	46.32 ±0.03	42.81 ±0.01	olv3 data	46.34 ±0.27	
TiO ₂	4.01 ±0.08	-	3.97 ±0.05	4.53 ±0.17	-	4.06 ±0.05	
Al ₂ O ₃	13.41 ±0.12	-	13.74 ±0.06	12.97 ±0.01	-	12.91 ±0.05	
FeO*	13.41 ±0.07	-	13.49 ±0.02	14.10 ±0.03	-	13.47 ±0.22	
MnO	0.20 ±0.03	-	0.22 ±0.00	0.16 ±0.01	-	0.26 ±0.02	
MgO	5.23 ±0.08	-	5.33 ±0.04	5.71 ±0.02	-	4.45 ±0.03	
CaO	9.99 ±0.08	-	10.24 ±0.10	10.41 ±0.01	-	9.38 ±0.04	
Na ₂ O	3.62 ±0.05	-	3.62 ±0.01	3.74 ±0.24	-	3.93 ±0.04	
K ₂ O	1.12 ±0.01	-	1.11 ±0.01	1.09 ±0.00	-	1.51 ±0.01	
P ₂ O ₅	1.81 ±0.00	-	1.79 ±0.04	1.69 ±0.03	-	2.08 ±0.04	
SO ₂	0.40 ±0.04	-	0.42 ±0.06	0.64 ±0.07	-	0.21 ±0.06	
Total	98.08 ±0.51	-	100.25 ±0.09	97.85 ±0.20	-	98.61 ±0.36	
H ₂ O	0.96 ±.02	0.36 ±.02	1.07 ±.06	1.09 ±.11	0.75 ±.06	0.87 ±.06	
CO ₂ (ppm)	1834.65 ± 241.54	n.d.	1154.75 ± 170.44	n.d.	n.d.	927.7 ±176.1	
PEC%	1.60%	-	2.50%	10.40%	-	-	-

Table 5: Electron microprobe and fourier transform infrared spectrometry results of olivine hosted melt inclusions from the Pantelleria balloon sample

NA018 balloon sample								
Crystal ID	018_PLG1	018_PLG2	018_PLG3	018_PLG5	018_PLG7	018_PLG8a		
<i>Glass inclusion</i>								
SiO ₂	45.09 ±0.38	44.61 ±0.50	43.19 ±1.21	45.23 ±0.28	45.27 ±0.21	44.05 ±1.22		
TiO ₂	4.19 ±0.11	4.14 ±0.09	5.46 ±0.38	4.27 ±0.07	4.10 ±0.02	4.52 ±0.05		
Al ₂ O ₃	12.97 ±0.08	12.32 ±0.09	7.54 ±0.70	12.80 ±0.18	13.03 ±0.22	11.38 ±0.41		
FeO*	13.75 ±0.02	13.65 ±0.04	17.44 ±1.12	13.30 ±0.09	13.46 ±0.06	15.38 ±0.07		
MnO	0.21 ±0.02	0.24 ±0.01	0.33 ±0.04	0.21 ±0.04	0.23 ±0.04	0.23 ±0.01		
MgO	5.13 ±0.04	5.31 ±0.01	6.80 ±0.38	5.23 ±0.03	5.24 ±0.08	5.90 ±0.10		
CaO	9.35 ±0.16	7.95 ±0.23	9.09 ±0.72	9.64 ±0.17	8.95 ±0.21	9.52 ±0.15		
Na ₂ O	3.79 ±0.09	4.11 ±0.11	2.95 ±0.28	3.85 ±0.12	4.17 ±0.14	3.48 ±0.17		
K ₂ O	1.65 ±0.04	2.91 ±0.02	2.05 ±0.22	1.38 ±0.06	1.90 ±0.12	1.60 ±0.09		
P ₂ O ₅	1.90 ±0.05	1.88 ±0.05	2.38 ±0.12	1.89 ±0.05	1.80 ±0.04	1.90 ±0.06		
SO ₂	0.49 ±0.08	0.43 ±0.07	0.60 ±0.07	0.45 ±0.01	0.52 ±0.06	0.42 ±0.04		
Total	98.52 ±0.08	97.52 ±0.18	97.82 ±0.26	98.25 ±0.11	98.67 ±0.17	98.37 ±1.61		
H ₂ O	0.33 ±0.02	0.99 ±0.15	0.37 ±0.03	0.43 ±0.04	1.31 ±0.16	0.29 ±0.05		
CO ₂ (ppm)	n.d	n.d	n.d	n.d	n.d.	n.d		-

Table 6: Electron microprobe and fourier transform infrared spectrometry results of plagioclase hosted melt inclusions from the Pantelleria balloon sample

018_PLG8b	018_PLG9a	018_PLG9b	018_PLG10	018_PLG11a	018_PLG11b	018_PLG12	018_PLG13
45.50 ±1.12	45.69 ±0.21	olv9a data	44.13 ±0.13	45.95 ±0.02	-	43.78 ±0.14	45.68 ±0.09
4.69 ±0.28	4.17 ±0.101	-	4.00 ±0.11	4.23 ±0.01	-	4.38 ±0.06	4.73 ±0.12
10.93 ±1.48	12.75 ±0.06	-	11.06 ±0.49	12.78 ±0.08	-	11.98 ±0.10	12.25 ±0.09
15.51 ±1.15	13.79 ±0.06	-	14.20 ±0.11	13.45 ±0.00	-	15.29 ±0.28	15.12 ±0.11
0.24 ±0.00	0.25 ±0.05	-	0.27 ±0.02	0.2 ±0.01	-	0.30 ±0.01	0.26 ±0.03
5.93 ±0.49	5.10 ±0.04	-	5.85 ±0.16	4.94 ±0.04	-	5.55 ±0.08	5.51 ±0.14
9.38 ±0.08	9.59 ±0.32	-	8.29 ±0.50	8.92 ±0.08	-	9.58 ±0.06	9.80 ±0.10
3.41 ±0.39	3.81 ±0.08	-	2.81 ±0.06	3.62 ±0.11	-	3.78 ±0.14	3.66 ±0.06
1.76 ±0.04	1.48 ±0.14	-	3.11 ±0.39	1.61 ±0.07	-	1.54 ±0.02	1.30 ±0.03
2.02 ±0.17	1.82 ±0.07	-	1.76 ±0.04	1.88 ±0.04	-	1.89 ±0.08	1.84 ±0.08
0.26 ±0.05	0.44 ±0.07	-	0.51 ±0.03	0.37 ±0.02	-	0.45 ±0.07	0.30 ±0.03
99.62 ±0.92	98.90 ±0.27	-	95.99 ±0.32	97.93 ±0.16	-	98.51 ±0.15	100.44 ±0.39
0.26 ±0.06	0.23 ±0.01	0.67 ±0.08	0.17 ±0.02	1.07 ±0.03	0.67 ±0.01	0.22 ±0.01	0.6 ±0.01
n.d	n.d	n.d	n.d	979.94 ±178.8	n.d.	n.d.	n.d.

Table 6 continued...

Socorro balloon sample						
Crystal ID	Soc_OLV1	SOC_OLV2	Soc_OLV3	SOC_OLV4a	SOC_OLV4b	SOC_OLV5
<i>Glass inclusion</i>						
SiO ₂	46.93 ±0.11	olv1 data	47.74 ±0.10	44.86 ±0.44	olv4a data	47.42 ±0.16
TiO ₂	3.33 ±0.04	-	2.74 ±0.08	3.65 ±0.14	-	3.00 ±0.04
Al ₂ O ₃	14.29 ±0.03	-	15.66 ±0.07	14.73 ±0.18	-	14.46 ±0.10
FeO*	11.55 ±0.09	-	10.39 ±0.07	14.01 ±0.05	-	11.60 ±0.07
MnO	0.19 ±0.03	-	0.14 ±0.03	0.22 ±0.03	-	0.17 ±0.02
MgO	6.19 ±0.20	-	5.98 ±0.06	4.91 ±0.02	-	5.80 ±0.10
CaO	9.79 ±0.15	-	10.39 ±0.01	9.58 ±0.16	-	9.48 ±0.02
Na ₂ O	3.46 ±0.03	-	3.31 ±0.08	3.35 ±0.13	-	3.46 ±0.11
K ₂ O	1.13 ±0.02	-	0.86 ±0.04	1.02 ±0.03	-	1.22 ±0.01
P ₂ O ₅	1.17 ±0.05	-	0.52 ±0.02	0.97 ±0.03	-	1.75 ±0.05
SO ₂	0.34 ±0.06	-	0.27 ±0.02	0.29 ±0.04	-	0.25 ±0.01
Total	98.37 ±0.22	-	98.00 ±0.21	97.59 ±0.63	-	98.61 ±0.07
H ₂ O	0.76 ±0.05	0.9 ±0.04	0.91 ±0.07	0.81 ±0.03	0.49 ±0.02	0.92 ±0.02
CO ₂ (ppm)	1555.02 ± 157.89	3512.31 ± 295.06	2713.39 ± 231.05	1523.23 ± 260.06	n.d.	467.96 ± 52.63
PEC %	3.80%	-	3.60%	0.40%	-	2.70%

Table 7: Electron microprobe and fourier transform infrared spectrometry results of olivine hosted melt inclusions from the Socorro balloon sample

SOC_OLV6	SOC_OLV7	SOC_OLV8	Soc_OLV9	SOC_OLV11a	Soc_OLV11b
48.37 ±0.61	45.89 ±0.19	47.50 ±0.25	45.63 ±0.08	48.89 ±0.38	olv11a data -
3.18 ±0.12	3.39 ±0.14	3.11 ±0.03	4.67 ±0.08	3.36 ±0.19	-
15.54 ±0.37	13.62 ±0.07	14.68 ±0.07	13.78 ±0.02	15.45 ±0.40	-
9.88 ±0.85	12.07 ±0.12	11.36 ±0.13	12.81 ±0.07	9.88 ±0.52	-
0.16 ±0.03	0.17 ±0.02	0.17 ±0.02	0.22 ±0.02	0.12 ±0.03	-
5.72 ±0.50	6.26 ±0.05	5.99 ±0.01	6.22 ±0.05	5.85 ±2.30	-
11.20 ±0.92	9.77 ±0.16	9.86 ±0.08	10.19 ±0.07	10.40 ±0.98	-
3.29 ±0.26	3.13 ±0.01	3.54 ±0.15	3.23 ±0.08	3.53 ±0.17	-
0.94 ±0.06	1.05 ±0.02	0.96 ±0.02	0.93 ±0.03	0.92 ±0.07	-
0.77 ±0.03	1.37 ±0.04	0.61 ±0.02	1.25 ±0.02	0.62 ±0.06	-
0.29 ±0.03	0.31 ±0.07	0.28 ±0.01	0.35 ±0.09	0.27 ±0.02	-
99.34 ±0.09	97.03 ±0.37	98.06 ±0.31	99.28 ±0.29	99.29 ±0.13	-
1.08 ±0.04	n.d.	0.95 ±0.04	0.93 ±0.04	0.31 ±0.05	0.18 ±0.02
n.d.	n.d.	2050.72 ±168.57	1614.93 ±212.83	505.99 ±79.96	330.74 ±85.88
2.60%	4.80%	3%	3.60%	4.60%	-

Table 7 continued...

Socorro balloon sample									
Crystal ID	SOC_PLG1a	SOC_PLG1b	SOC_PLG1c	SOC_PLG2a	SOC_PLG2b	Soc_PLG3			
Glass inclusion									
SiO ₂	48.14 ±0.22	plg1a data	-	plg1a data	-	50.06 ±0.75	50.21 ±0.36	47.51 ±0.32	
TiO ₂	3.70 ±0.05	-	-	-	-	3.20 ±0.07	3.09 ±0.12	3.52 ±0.04	
Al ₂ O ₃	14.65 ±0.02	-	-	-	-	15.07 ±0.19	14.63 ±0.07	14.39 ±0.04	
FeO*	12.02 ±0.11	-	-	-	-	10.84 ±0.15	10.80 ±0.04	12.04 ±0.03	
MnO	0.19 ±0.02	-	-	-	-	0.18 ±0.04	0.17 ±0.01	0.18 ±0.03	
MgO	4.16 ±0.05	-	-	-	-	3.92 ±0.24	4.10 ±0.01	4.49 ±0.04	
CaO	8.81 ±0.14	-	-	-	-	8.36 ±0.14	8.04 ±0.23	8.98 ±0.04	
Na ₂ O	4.06 ±0.10	-	-	-	-	3.89 ±0.16	4.07 ±0.06	4.14 ±0.12	
K ₂ O	1.23 ±0.04	-	-	-	-	1.35 ±0.08	1.47 ±0.16	1.30 ±0.02	
P ₂ O ₅	1.33 ±0.03	-	-	-	-	1.43 ±0.06	1.34 ±0.04	1.69 ±0.07	
SO ₂	0.41 ±0.04	-	-	-	-	0.24 ±0.02	0.25 ±0.06	0.35 ±0.04	
Total	98.69 ±0.30	-	-	-	-	98.52 ±0.46	98.17 ±0.30	98.60 ±0.40	
H ₂ O	0.9 ±0.04	0.89 ±0.04	0.79 ±0.06	0.17 ±0.01	0.47 ±0.04	0.66 ±0.05			
CO ₂ (ppm)	1233.97 ±191.3	1366.16 ±141.5	1245.61 ±144.7	n.d	-	787.44 ±78.6			

Table 8: Electron microprobe and fourier transform infrared spectrometry results of plagioclase hosted melt inclusions from the Socorro balloon sample

SOC_PLG5	Soc_PLG6	Soc_PLG7a	Soc_PLG7b	Soc_PLG8	Soc_PLG9a	Soc_PLG9b	SOC_PLG9c
plg3data	-	48.75 ±0.06	47.75 ±0.18	49.38 ±0.14	47.45 ±0.21	plg9a data	-
-	2.74 ±0.07	3.04 ±0.02	3.09 ±0.10	2.63 ±0.08	3.81 ±0.02	-	-
-	14.16 ±0.07	13.58 ±0.06	13.85 ±0.01	14.42 ±0.08	14.17 ±0.08	-	-
-	11.48 ±0.02	11.84 ±0.12	11.65 ±0.09	11.30 ±0.10	12.37 ±0.16	-	-
-	0.19 ±0.02	0.23 ±0.02	0.21 ±0.03	0.20 ±0.04	0.22 ±0.02	-	-
-	5.64 ±0.04	5.81 ±0.03	5.77 ±0.02	6.00 ±0.01	4.81 ±0.03	-	-
-	9.49 ±0.05	9.17 ±0.13	9.60 ±0.04	9.22 ±0.07	9.20 ±0.16	-	-
-	3.85 ±0.13	3.73 ±0.08	3.72 ±0.10	3.70 ±0.10	4.09 ±0.18	-	-
-	1.09 ±0.02	1.16 ±0.07	1.03 ±0.03	1.06 ±0.01	1.28 ±0.01	-	-
-	0.58 ±0.01	0.55 ±0.01	0.67 ±0.02	0.43 ±0.05	0.90 ±0.03	-	-
-	0.28 ±0.04	0.26 ±0.04	0.27 ±0.02	0.28 ±0.03	0.16 ±0.03	-	-
-	98.27 ±0.11	97.74 ±0.24	97.61 ±0.27	98.62 ±0.20	98.45 ±0.40	-	-
0.65 ±0.05	0.85 ±0.02	0.39 ±0.05	0.57 ±0.00	0.89 ±0.01	0.42 ±0.05	0.43 ±0.05	0.37 ±0.08
896.68 ±156.5	318.38 ±52	418.94 ±73.5	371.97 ±42.7	1497.66 ±123.6	n.d	n.d	n.d

Table 8 continued....

Soc_PLG10	Soc_PLG11
47.63 ±0.45	45.45 ±1.14
3.59 ±0.01	3.58 ±0.12
14.20 ±0.12	13.48 ±0.27
11.97 ±0.16	12.42 ±0.24
0.20 ±0.01	0.22 ±0.02
4.74 ±0.06	5.10 ±0.08
8.91 ±0.10	9.12 ±0.15
3.99 ±0.09	4.17 ±0.12
1.15 ±0.01	1.22 ±0.07
1.50 ±0.03	1.36 ±0.05
0.37 ±0.02	0.35 ±0.03
98.25 ±0.58	96.48 ±1.61
0.88 ±0.03	0.74 ±0.03
1517.68 ±213.8	557.32 ±35.4

Table 8 continued...

Figure 1: Map showing the island of Pantelleria, southwest Sicily. The location of the 1891 eruption vent is shown by a star. Inset map shows locations of Pantelleria in the Mediterranean Sea. Maps derived from Google Earth.

Figure 2: Map showing the island of Socorro, west Mexico. The location of the 1993 eruption ent is shown by a star. Inset map shows locations of Socorro in the Pacific Ocean. Maps derived from google earth.

Figure 3: Photomicrographs of matrix glass and crystals from sample NA018-018. A. Matrix glass and crystals in normal light. B. Matrix glass and crystals in crossed polars. Backscatter electron images (BSE) of matrix glass and crystals showing tachylite texture (C) and sideromelane (D). Melt inclusions entrapped in olivine (E) and plagioclase (F) phenocrysts in normal light. All scale bars shown in images are 1mm across

Figure 4: Photomicrographs of matrix glass and crystals from the Socorro balloon sample. A. Matrix glass and crystals in normal light. B. Matrix glass and crystals in crossed polars. Backscatter electron images (BSE) of matrix glass and crystals showing tachylite texture (C) and sideromelane (D). Melt inclusions entrapped in olivine (E) and plagioclase (F) phenocrysts in normal light. All scale bars shown in images are 1mm across.

Figure 5: Compositional plots of results from electron microprobe analysis of Pantelleria samples. Values are normalized to 100% and are plotted with data presented in Kelly et al. (2014). Closed circles, triangles, and squares are melt inclusion analysis. Open circles are matrix glass analysis. Olivine melt inclusions have been corrected for post entrapment crystallization.

Figure 6: Compositional plots of results from electron microprobe analysis of Socorro samples. Values have been normalized to 100% and are plotted with data presented in Siebe et al. (1995). Closed circles and squares are melt inclusion analysis. Open circles are matrix glass analysis. Olivine hosted melt inclusions have been corrected for post entrapment crystallization.

Figure 7: H₂O data and carbon dioxide values for melt inclusions from Pantelleria and Socorro, with Kueppers et al. (2012) melt inclusion data from Azores samples. The purple field outlines data presented in Sides et al. (2014) of compiled volatile data from Hawaiian samples produced by various eruption styles. The blue field outlines MORB volatile ranges based on data from Saal et al. (2002).

Figure 8: Pantelleria volatile contents plotted in relation to degassing paths of NA 018-OLV 2 with differing amounts of exsolved gas. Calculations for degassing paths and isobars were done using VOLATILECALC (Newman & Lowenstern 2002). Dashed lines show open and closed degassing paths

Figure 9: Pantelleria volatile contents plotted in relation to with open and closed system degassing paths of NA 018-OLV 2. Calculations for degassing paths and isobars (dashed lines) were done using SolEx (Witham et al., 2012).

Figure 10: Socorro volatile contents plotted in relation to degassing paths of SOC-OLV 2 with differing amounts of exsolved gas. Calculations for degassing paths and isobars were done using VOLATILECALC (Newman & Lowenstern, 2002).

Figure 11: Socorro volatile contents plotted in relation to degassing path of SOC-OLV 2 in a 2-step degassing process. First undergoing open system degassing behavior, then shifting to a range of closed system behaviors. Calculations for degassing paths and isobars were done using VOLATILECALC (Newman & Lowenstern, 2002).

Figure 12: Socorro volatile contents plotted in relation to open and closed system degassing paths of SOC-OLV 2. Calculations for degassing paths and isobars were done using SolEx (Witham et al., 2012).

Figure 13: A). Calculated terminal velocities of basaltic balloons as a function of size and density. Dashed vertical lines show predicted balloon densities for Socorro and Foerstner eruptions based on calculations using D-compress with volatile contents measured for each event B). Calculated time in seconds that balloon samples of varying size would need to reach the sea surface from a vent at 250 m depth. Dashed lines as described in A).

APPENDIX

Raw data from electron microprobe scans and FTIR analysis

NA018 balloon sample										
XTL composition	Na018_olv1_s1	Na018_olv1_s2	Na018_olv2_s1	Na018_olv2_s2	Na018_olv3_s1	Na018_olv3_s2	Na018_olv4_s1	Na018_olv5_s1		
SiO ₂	37.61	37.77	38.1	37.89	37.4	37.47	37.33	37.46		
TiO ₂	0.09	0.13	0.06	0.05	0.1	0.09	0.13	0.14		
Al ₂ O ₃	0.04	0.08	0	0	0.01	0.02	0.02	0.03		
FeO*	24.76	25.46	24.45	24.99	26.8	26.56	25.87	26.36		
MnO	0.44	0.46	0.42	0.44	0.5	0.43	0.5	0.5		
MgO	36.78	35.9	37.31	36.94	35.39	35.63	35.92	35.67		
CaO	0.6	0.52	0.3	0.32	0.34	0.34	0.51	0.38		
Na ₂ O	0.03	0	0	0	0.02	0.04	0.02	0		
K ₂ O	0.01	0.01	0	0	0	0	0.01	0.01		
P ₂ O ₅	0.6	0.24	0.19	0.17	0.38	0.34	0.27	0.36		
SO ₂	0	0	0.01	0.02	0.03	0.02	0.02	0.01		
Total	100.96	100.57	100.84	100.82	100.97	100.94	100.6	100.92		

Table A1: Electron microprobe scans of minerals from the Foerstner, Pantelleria balloon sample

NA018_olvg_s1	NA018_PLG1_s1	NA018_PLG1_s2	NA018_PLG1_s3	NA018_PLG2_s1	NA018_PLG2_s2	NA018_PLG2_s3	NA018_PLG3_s1	NA018_PLG3_s2
37.23	53.69	53.68	53.64	53.24	53.23	53.37	53.17	53.2
0.1	0.13	0.13	0.18	0.14	0.11	0.15	0.13	0.16
0.03	29.34	29.2	29.41	29.61	29.46	29.28	29.51	29.53
25.43	0.72	0.85	0.74	0.77	0.69	0.8	0.73	0.74
0.45	0.03	0	0	0	0.01	0	0.01	0
36.27	0.11	0.18	0.11	0.12	0.12	0.12	0.14	0.14
0.48	11.81	11.51	11.78	11.86	11.59	11.54	12.02	12.09
0	4.72	4.94	4.36	4.77	4.74	4.61	4.22	4.45
0.01	0.29	0.29	0.31	0.29	0.28	0.3	0.28	0.28
0.46	0.06	0.03	0.03	0.02	0.03	0.06	0.03	0.05
0	0.01	0	0	0.03	0.02	0.02	0	0
100.46	100.91	100.81	100.56	100.85	100.28	100.25	100.24	100.64

Table A1 continued...

NA018_PLG3_s3	NA018_PLG4_s1	NA018_PLG4_s2	NA018_PLG5_s1	NA018_PLG5_s2	NA018_PLG5_s3	NA018_PLG3_s3	NA018_PLG4_s1	NA018_PLG4_s2
53.17	53.41	54.39	53.13	53.14	53.2	53.17	53.41	54.39
0.14	0.15	0.14	0.19	0.12	0.17	0.14	0.15	0.14
29.39	29.29	28.75	29.63	29.8	29.54	29.39	29.29	28.75
0.82	0.73	0.81	0.69	0.73	0.75	0.82	0.73	0.81
0.01	0.01	0.02	0.03	0.02	0	0.01	0.01	0.02
0.14	0.11	0.14	0.14	0.1	0.11	0.14	0.11	0.14
11.67	11.54	11.08	12.24	11.99	11.86	11.67	11.54	11.08
4.31	4.6	4.94	4.14	4.66	4.47	4.31	4.6	4.94
0.29	0.29	0.31	0.28	0.24	0.28	0.29	0.29	0.31
0.03	0.06	0.02	0.02	0.04	0.05	0.03	0.06	0.02
0	0.01	0.01	0.01	0	0.03	0	0.01	0.01
99.97	100.2	100.61	100.5	100.84	100.46	99.97	100.2	100.61

Table A1 continued...

NA018_PLG5_s1	NA018_PLG5_s2	NA018_PLG5_s3	NA018_PLG6_s1	NA018_PLG6_s2	NA018_PLG6_s3	NA018_PLG7_s1	NA018_PLG7_s2	NA018_PLG8_s1
53.13	53.14	53.2	53.72	53.84	53.25	53.73	53.97	53.92
0.19	0.12	0.17	0.15	0.15	0.09	0.14	0.16	0.12
29.63	29.8	29.54	29.37	29.39	29.55	29.56	29.35	29.32
0.69	0.73	0.75	0.82	0.9	0.92	0.71	0.81	0.85
0.03	0.02	0	0	0.01	0	0	0	0
0.14	0.1	0.11	0.11	0.11	0.11	0.1	0.1	0.12
12.24	11.99	11.86	11.64	11.56	11.79	11.71	11.61	11.56
4.14	4.66	4.47	4.57	4.94	4.21	4.73	4.53	4.74
0.28	0.24	0.28	0.27	0.29	0.27	0.26	0.3	0.29
0.02	0.04	0.05	0	0.01	0.04	0.04	0.04	0.08
0.01	0	0.03	0.03	0	0.01	0	0	0
100.5	100.84	100.46	100.68	101.2	100.24	100.98	100.87	101

Table A1 continued...

Na018_PLG8_s2	Na018_PLG8_s3	Na018_PLG9_s1	Na018_PLG9_s2	Na018_PLG9_s3	Na018_CPX1_s1	Na018_CPX1_s2	Na018_CPX1_s3	Na018_CPX1_s4
53.37	53.46	53.33	53.68	53.27	47.39	46.39	47.04	46.92
0.17	0.15	0.08	0.18	0.07	2.64	2.74	2.84	2.91
29.17	29.45	29.59	29.31	29.78	5.45	5.29	5.58	5.75
0.83	0.85	0.85	0.85	0.79	8.97	9.55	9.4	9.1
0.01	0.05	0	0	0.03	0.17	0.23	0.21	0.12
0.12	0.13	0.08	0.13	0.11	13	13.07	12.96	13.12
11.72	11.67	11.81	11.65	11.78	21.75	21.75	21.32	21.52
4.7	4.75	4.84	4.81	4.46	0.56	0.47	0.54	0.45
0.31	0.29	0.27	0.3	0.27	0	0.01	0.01	0
0.03	0.03	0.02	0.02	0.04	0.02	1.1	0.22	0.1
0	0.01	0	0.04	0	0.01	0.02	0.01	0
100.43	100.84	100.87	100.97	100.6	99.95	100.62	100.12	99.99

Table A1 continued...

NA018_CPX1_s5	NA018_CPX2_s1	NA018_CPX2_s2	NA018_CPX3_s1	NA018_CPX3_s2	NA018_CPX4_s1	NA018_CPX4_s2	NA018_CPX4_s3	NA018_CPX5_s1
48.07	46.84	47	50.93	47.46	47.24	47.92	50.34	47.75
2.55	3.13	2.72	1.35	1.41	2.58	2.55	1.41	2.42
5.12	5.95	5.41	2.62	2.78	5.49	5.26	2.67	5.22
8.62	9.05	8.81	8.7	9.37	8.88	8.81	8.9	8.77
0.14	0.18	0.16	0.24	0.25	0.14	0.17	0.21	0.23
13.44	12.99	13.29	15.75	14.31	13.16	13.49	15.19	13.37
22.04	21.11	20.41	19.84	21.06	21.24	20.99	20.15	21.16
0.5	0.38	0.39	0.28	0.3	0.5	0.42	0.25	0.42
0.01	0	0	0.01	0	0	0	0.01	0
0.05	0.05	0.03	0.06	2.79	0.05	0.07	0.49	0.2
0	0	0	0	0	0	0	0	0.01
100.54	99.68	98.22	99.78	99.73	99.28	99.68	99.62	99.55

Table A1 continued...

Na018_CPX5_s2	Na018_CPX5_s3	Na018_CPX6_s1	Na018_CPX6_s2	Na018_CPX7_s1	Na018_CPX7_s2	Na018_CPX7_s3	Na018_CPX8_s1	Na018_CPX8_s2	Na018_CPX8_s3	Na018_CPX8_s4
47.68	46.09	46.84	47	47.08	48.08	46.87	50.47	46.9	46.71	47.71
2.64	2.7	3.13	2.72	2.72	2.22	2.84	1.55	2.78	2.99	2.59
5.28	5.36	5.95	5.41	5.62	5.36	5.95	2.97	6.04	6.19	5.44
8.83	8.65	9.05	8.81	9.35	9.1	9.57	9.43	9.25	9.27	8.95
0.18	0.17	0.18	0.16	0.22	0.19	0.17	0.25	0.18	0.21	0.23
13.4	12.85	12.99	13.29	13.11	13.82	12.96	15.96	13.08	12.95	13.43
20.85	22.01	21.11	20.41	20.6	20.62	20.44	18.69	20.64	20.52	20.7
0.49	0.41	0.38	0.39	0.54	0.63	0.59	0.43	0.48	0.48	0.43
0	0	0	0	0	0.01	0	0	0	0	0
0.13	1.41	0.05	0.03	0.22	0.05	0.07	0.04	0.05	0.07	0.06
0	0	0	0	0.01	0	0.02	0.05	0	0.02	0.02
99.48	99.65	99.68	98.22	99.47	100.08	99.48	99.84	99.4	99.41	99.56

Table A1 continued...

Socorro balloon sample													
XTL composition													
	SOCL_olv1_s1	SOCL_olv1_s2	SOCL_olv1_s3	SOCL_olv2_s1	SOCL_olv2_s2	SOCL_olv3_s1	SOCL_olv3_s2	SOCL_olv3_s3	SOCL_olv4_s1	SOCL_olv4_s2	SOCL_olv4_s3	SOCL_olv4_s4	SOCL_olv4_s5
SiO ₂	38.14	37.87	38.48	38.43	38.47	38.79	38.61	38.57	38.56	38.53			
TiO ₂	0.03	0.1	0.03	0.04	0.06	0.04	0.06	0.03	0.05	0.04			
Al ₂ O ₃	0.03	0.03	0.03	0.04	0.05	0.03	0.01	0.02	0.02	0.03			
FeO*	22.46	23.02	22.03	22.19	22.09	21.31	21.42	22.62	22.11	21.79			
MnO	0.33	0.35	0.31	0.39	0.37	0.34	0.37	0.36	0.35	0.33			
MgO	38.99	38.55	39.13	39.15	39.07	40.12	39.71	38.94	39.39	39.37			
CaO	0.32	0.31	0.28	0.27	0.27	0.24	0.26	0.26	0.28	0.29			
Na ₂ O	0	0.07	0	0	0.06	0.03	0	0.03	0.01	0			
K ₂ O	0	0	0.01	0.01	0	0.01	0	0	0.01	0.01			
P ₂ O ₅	0.07	0.11	0.1	0.05	0.06	0.21	0.07	0.08	0.12	0.17			
SO ₂	0.02	0.01	0.02	0.03	0	0	0.02	0	0	0			
Total	100.39	100.42	100.42	100.6	100.5	101.12	100.53	100.91	100.9	100.56			

Table A2: Electron microprobe scans of minerals from the Socorro balloon sample

SOCR_olv4_s3	SOCR_olv5_s1	SOCR_olv1_s1	SOCR_olv1_s2	SOCR_olv1_s3	SOCR_olv2_s1	SOCR_olv2_s2	SOCR_olv2_s3	SOCR_olv3_s1	SOCR_olv3_s2
38.51	37.96	38.33	38.31	38.64	38.52	38.44	38.5	38.66	38.69
0.05	0.06	0.05	0.05	0.11	0.08	0.07	0.02	0.04	0.09
0.04	0.03	0.01	0.02	0.05	0.03	0.03	0	0.03	0.02
22.18	23.65	23.29	23.2	22.57	21.98	22.31	22.29	21.43	21.75
0.3	0.32	0.38	0.37	0.34	0.33	0.33	0.33	0.37	0.32
39.59	38.16	38.76	38.62	39.03	39.4	39.32	39.13	39.94	40.1
0.29	0.32	0.24	0.3	0.23	0.22	0.22	0.27	0.27	0.27
0.06	0.01	0	0.01	0	0.02	0.05	0.04	0.03	0.01
0	0.01	0	0	0	0	0	0	0	0
0.11	0.12	0.09	0.06	0.18	0.15	0.1	0.08	0.18	0.19
0	0	0	0.01	0	0.02	0	0	0	0
101.13	100.64	101.15	100.95	101.15	100.75	100.87	100.66	100.95	101.44

Table A2 continued...

SOCR_olv4_s1	SOCR_olv4_s2	SOCR_olv4_s3	SOCR_olv4_s4	SOCL_PLG1_s1	SOCL_PLG1_s2	SOCL_PLG1_s3	SOCL_PLG2_s1	SOCL_PLG2_s2	SOCL_PLG3_s1
38.33	38.95	38.49	38.6	53.24	52.05	52.84	53.08	52.65	52.85
0.02	0.04	0.03	0.05	0.15	0.15	0.16	0.17	0.22	0.17
0.03	0.02	0.04	0.01	29.81	30.46	29.87	29.79	29.81	29.96
23.28	21.42	22.06	21.34	0.81	0.69	0.79	0.74	0.83	0.71
0.32	0.31	0.32	0.28	0.01	0	0	0	0.02	0.06
38.62	40.22	39.67	40.42	0.15	0.13	0.14	0.13	0.16	0.13
0.26	0.17	0.21	0.21	12.01	12.93	12.4	12.22	12.44	12.5
0	0.04	0.01	0.01	4.51	3.89	4.39	4.2	4	4.21
0	0	0	0	0.24	0.19	0.24	0.25	0.23	0.24
0.06	0.15	0.14	0.03	0.03	0.01	0.03	0.03	0	0.01
0	0.02	0	0	0	0.05	0.03	0.02	0	0
100.92	101.34	100.97	100.95	100.96	100.55	100.89	100.63	100.36	100.84

Table A2 continued...

SOCL_PLG3_s2	SOCL_PLG3_s3	SOCR_PLG1_s1	SOCR_PLG1_s2	SOCR_PLG1_s3	SOCR_PLG2_s1	SOCR_PLG2_s2	SOCR_PLG2_s3
52.77	52.52	53.77	53.23	53.86	52.6	52.4	52.54
0.12	0.14	0.16	0.12	0.18	0.12	0.14	0.11
30.03	30.01	29.41	29.56	29.08	30.45	30.2	30.23
0.69	0.65	0.81	0.75	0.87	0.64	0.72	0.76
0.01	0	0	0	0	0	0.04	0
0.13	0.14	0.18	0.13	0.14	0.14	0.15	0.14
12.47	12.57	11.84	12.21	11.49	12.8	12.57	12.81
4.33	4.08	4.6	4.37	4.74	4.15	4.41	4.12
0.23	0.22	0.26	0.26	0.28	0.19	0.21	0.22
0	0.04	0.03	0	0.03	0.02	0.04	0.02
0.01	0	0	0	0	0	0	0.03
100.79	100.37	101.06	100.63	100.67	101.11	100.88	100.98

Table A2 continued...

SOCR_PLG3_s1	SOCR_PLG3_s2	SOCR_PLG3_s3	SOCR_PLG4_s1	SOCR_PLG4_s2	SOCR_PLG4_s3
53.67	54.15	52.46	52.5	52.3	52.74
0.11	0.11	0.12	0.17	0.15	0.08
29.55	29.3	30.41	30.28	30.35	30.11
0.6	0.61	0.6	0.75	0.71	0.65
0	0.04	0	0	0	0.03
0.11	0.08	0.11	0.11	0.15	0.13
11.7	11.52	12.7	12.66	12.56	12.53
4.75	4.94	4.24	4.1	4.36	4.26
0.24	0.26	0.21	0.21	0.21	0.23
0.03	0.05	0.03	0	0.03	0.01
0.03	0	0	0.01	0	0.02
100.79	101.06	100.88	100.79	100.82	100.79

Table A2 continued...

NA018 balloon sample

Matrix glass

	NA018_GL1_s1	NA018_GL1_s2	NA018_GL1_s3	NA018_GL1_s4	NA018_GL1_s5	NA018_GL2_s1	NA018_GL2_s2	NA018_GL2_s3	NA018_GL2_s4
<i>Glass composition</i>									
SiO ₂	46.52	46.52	46.86	46.85	46.91	46.08	46.95	47.01	47.24
TiO ₂	4.3	4.3	4.16	4.1	4.34	4.5	4.22	3.98	4.01
Al ₂ O ₃	12.8	13.01	13.09	13.07	13.29	12.54	12.81	12.25	12.94
FeO*	13.93	13.74	13.5	13.8	13.21	15.06	13.91	13.93	13.24
MnO	0.28	0.26	0.28	0.3	0.29	0.23	0.29	0.23	0.37
MgO	4.68	4.36	4.52	4.43	3.99	3.96	3.86	4.43	4.53
CaO	9	9.41	9.58	9.11	9.4	8.75	9.63	9.38	9.13
Na ₂ O	4.22	3.95	3.68	4.13	4.12	3.97	3.68	3.72	3.62
K ₂ O	1.99	1.88	1.64	1.82	1.96	2.02	2.22	2.3	2.17
P ₂ O ₅	2.08	2.1	2.02	2.11	2.12	2.16	2.13	2.29	2.11
SO ₂	0.26	0.24	0.2	0.28	0.23	0.19	0.23	0.28	0.23
Total	100.05	99.77	99.52	100	99.86	99.47	99.93	99.82	99.58

Table A3 Electron microprobe scans of matrix glass from the Foerstner, Pantelleria balloon sample

NA018_GL3_s2	NA018_GL3_s3	NA018_GL3_s4	NA018_GL3_s5	NA018_GL4_s1	NA018_GL4_s2	NA018_GL4_s3	NA018_GL4_s4	NA018_GL4_s5	NA018_GL5_s1	NA018_GL5_s2	NA018_GL5_s3
47.1	46.31	46.47	47.02	46.69	46.79	46.52	46.75	46.84	46.71	46.65	46.57
5.01	3.89	3.82	4	4.17	4.19	4.2	4.32	4.2	4.2	4.11	4.16
12.24	11.52	11.91	12.11	13.04	13.08	13.12	13.07	13	13.06	13.04	13.09
11.8	15.61	15.37	13.81	13.72	13.93	13.69	13.86	13.67	13.76	13.73	13.45
0.21	0.38	0.34	0.32	0.18	0.25	0.21	0.26	0.29	0.25	0.29	0.28
4.19	3.72	4.09	4.15	4.61	4.62	4.55	4.5	4.62	4.53	4.59	4.53
11.57	10.6	10.6	9.73	9.38	9.28	9.24	9.37	9.31	9.35	9.45	9.28
4.07	3.91	3.52	3.96	3.75	3.91	4.07	3.86	3.98	3.73	3.81	3.88
1.39	1.9	1.67	2.14	1.49	1.45	1.47	1.47	1.48	1.49	1.48	1.48
2.55	2.32	2.24	2.32	2.03	2.11	2.05	2.06	2.05	2.03	2.16	2.1
0.09	0.21	0.18	0.17	0.23	0.17	0.24	0.17	0.25	0.24	0.25	0.2
100.23	100.37	100.22	99.72	99.29	99.79	99.38	99.7	99.7	99.37	99.56	99.02

Table A3 continued...

NA018_GL5_s4	NA018_GL5_s5	NA018_GL6_s1	NA018_GL6_s2	NA018_GL6_s3	NA018_GL6_s4	NA018_GL6_s5
46.54	46.81	46.68	46.78	45.45	46.68	46.97
4.38	4.15	4.3	4.25	4.6	4.29	4.22
12.86	13.13	13.07	12.95	11.99	13	13.15
13.65	13.46	13.69	14.07	15.71	13.77	13.41
0.27	0.27	0.24	0.23	0.29	0.23	0.25
4.74	4.56	4.62	4.59	5.14	4.52	4.48
9.33	9.28	9.22	9.19	9.72	9.06	9.4
3.88	3.71	3.87	3.81	3.67	3.79	4.25
1.46	1.51	1.64	1.73	1.37	1.66	1.61
1.99	2.05	2.18	2.16	2.46	2.1	2.14
0.2	0.16	0.15	0.25	0.73	0.23	0.24
99.3	99.09	99.67	100.02	101.12	99.33	100.11

Table A3 continued...

Socorro balloon sample
Matrix glass

	SOCL_GL1_s1	SOCL_GL1_s2	SOCL_GL1_s3	SOCL_GL1_s4	SOCL_GL1_s5	SOCL_GL2_s1	SOCL_GL2_s2	SOCL_GL2_s3	SOCL_GL2_s4	SOCL_GL2_s5	SOCL_GL3_s1
<i>Glass composition</i>											
SiO ₂	47.82	47.59	47.44	47.76	47.57	47.39	47.47	47.59	47.55	47.45	47.18
TiO ₂	3.74	3.88	3.8	3.8	3.8	3.85	3.79	3.95	3.81	3.97	3.75
Al ₂ O ₃	14.46	14.54	14.41	14.51	14.47	14.33	14.43	14.45	14.43	14.35	14.37
FeO*	12.59	12.41	12.55	12.6	12.27	12.43	12.51	12.66	12.37	12.42	12.87
MnO	0.18	0.22	0.21	0.16	0.2	0.19	0.2	0.16	0.2	0.23	0.18
MgO	4.96	4.99	4.88	4.94	5	4.93	4.94	4.82	4.98	4.9	4.95
CaO	9.16	9.19	9.2	9.32	9.3	9.34	9.23	9.23	9.28	9.39	9.32
Na ₂ O	3.9	3.87	3.73	4.08	3.83	3.99	3.77	4.02	3.38	3.87	3.73
K ₂ O	1.3	1.27	1.32	1.28	1.27	1.28	1.27	1.28	1.25	1.29	1.31
P ₂ O ₅	0.89	0.9	0.96	0.92	0.93	0.92	0.96	0.98	0.88	1.01	0.9
SO ₂	0.18	0.17	0.11	0.16	0.1	0.11	0.17	0.13	0.13	0.12	0.14
Total	99.18	99.02	98.6	99.53	98.74	98.76	98.74	99.27	98.26	99.01	98.69

Table A4: Electron microprobe scans of matrix glass from the Socorro balloon sample

SOCR_GL3_s2	SOCR_GL3_s3	SOCR_GL3_s4	SOCR_GL3_s5	SOCR_GL1_s1	SOCR_GL1_s2	SOCR_GL1_s3	SOCR_GL1_s4	SOCR_GL1_s5	SOCR_GL2_s1	SOCR_GL2_s2	SOCR_GL2_s3
47.1	47.28	48.05	47.35	48.15	47.76	47.54	47.84	47.61	48.1	47.39	47.96
4	3.7	4.05	3.85	3.98	3.99	4.39	3.98	4.27	4.1	4.2	4
14.34	14.4	15.17	14.42	13.79	14.07	12.86	14.07	13.67	14.18	12.84	14.25
12.65	12.39	11.66	12.49	12.51	13.36	16.27	14.09	14.09	13.43	14.87	12.57
0.2	0.2	0.2	0.18	0.21	0.28	0.24	0.2	0.21	0.25	0.25	0.15
4.84	4.88	4.07	4.95	5.3	4.77	4.47	4.49	4.58	4.36	5.26	4.24
9.11	9.15	9.2	9.21	9.2	9.01	6.69	8.25	7.8	8.59	8.74	9.37
3.8	3.88	4.03	3.86	4.03	3.65	4.27	4.28	4.16	3.95	3.65	4.13
1.29	1.27	1.38	1.28	2.07	2.01	2.61	1.54	2.36	1.91	2.26	1.93
0.92	0.94	1.02	0.86	0.93	0.96	0.97	0.92	0.97	0.93	1.04	1.03
0.09	0.2	0.17	0.18	0.23	0.16	0.18	0.13	0.17	0.14	0.16	0.11
98.33	98.28	98.99	98.64	100.4	100.03	100.5	99.8	99.9	99.95	100.65	99.72

Table A4 continued

SOCR_GL2_s4	SOCR_GL2_s5	SOCR_GL3_s1	SOCR_GL3_s2	SOCR_GL3_s3	SOCR_GL3_s4	SOCR_GL3_s5
48.17	48.53	47.96	47.83	46.55	48.18	47.74
3.87	3.98	3.93	3.83	3.99	4.08	4.02
13.54	14.32	14.25	14.28	13.37	14.17	14.18
14.25	13.94	13.84	12.55	13.03	12.67	12.93
0.27	0.22	0.27	0.21	0.18	0.25	0.26
4.51	3.85	4.94	4.99	5.23	4.76	5.02
7.89	8.76	9.27	8.93	8.97	9	8.77
4.03	4.61	4.48	4.35	4.29	4.2	4.2
2.25	1.46	1.09	1.65	1.55	1.66	1.59
0.96	1	0.96	0.97	0.86	0.9	0.97
0.19	0.16	0.13	0.11	0.14	0.1	0.12
99.92	100.82	101.11	99.69	98.16	99.99	99.79

Table A4 continued...

NAO18 balloon sample											
NAO18-OLV2_s1		NAO18-OLV2_s2	NAO18-OLV2_s3	NAO18_olv3_s1	NAO18_olv3_s2	NAO18_olv3_s3	NAO18_olv5_s1	NAO18_olv5_s2	NAO18_cpx_s1	NAO18_cpx_s2	NAO18_cpx_s3
<i>Glass inclusion</i>											
SiO ₂	44.89	45.58	44.49	46.5	46.53	46.55	44.25	44.73	46.54	46.45	46.03
TiO ₂	4.1	3.98	4.13	4.19	4.25	4.3	5.13	4.86	4.1	4.01	4.08
Al ₂ O ₃	13.49	13.74	13.64	14.11	14.11	14.01	14.43	14.2	12.92	12.96	12.86
FeO*	12.96	12.85	12.83	13.18	13.22	13.21	12.51	12.05	13.23	13.67	13.52
MnO	0.17	0.22	0.2	0.23	0.22	0.23	0.19	0.17	0.24	0.28	0.25
MgO	4.81	4.66	4.71	4.55	4.54	4.6	2.76	2.85	4.45	4.47	4.42
CaO	10.23	10.07	10.16	10.53	10.59	10.39	11.41	11.57	9.34	9.42	9.39
Na ₂ O	3.74	3.68	3.63	3.7	3.71	3.73	3.94	4.31	3.94	3.89	3.97
K ₂ O	1.15	1.13	1.15	1.15	1.13	1.14	1.2	1.2	1.5	1.51	1.51
P ₂ O ₅	1.84	1.84	1.84	1.82	1.79	1.88	1.84	1.88	2.04	2.1	2.11
SO ₂	0.37	0.45	0.41	0.4	0.38	0.5	0.65	0.76	0.14	0.26	0.22
Total	97.76	98.21	97.19	100.36	100.48	100.54	98.3	98.58	98.43	99.02	98.36

Table A5: Electron microprobe scans of olivine and clinopyroxene hosted melt inclusions from the Foerstner, Pantelleria balloon sample

NA018 balloon sample									
	NA018_PLG1_s1	NA018_PLG1_s2	NA018_PLG1_s3	NA018_PLG2_s1	NA018_PLG2_s2	NA018_PLG3_s1	NA018_PLG3_s2	NA018_PLG3_s3	NA018_PLG5_s1
Glass inclusion									
SiO ₂	44.67	45.2	45.41	44.25	44.96	43.84	43.94	41.79	45.14
TiO ₂	4.3	4.17	4.09	4.2	4.07	5.23	5.24	5.9	4.27
Al ₂ O ₃	12.89	12.99	13.04	12.38	12.25	7.96	7.93	6.73	12.97
FeO*	13.77	13.73	13.75	13.67	13.62	16.77	16.82	18.73	13.36
MnO	0.2	0.19	0.23	0.23	0.25	0.29	0.34	0.36	0.21
MgO	5.17	5.1	5.13	5.3	5.32	6.54	6.63	7.24	5.22
CaO	9.42	9.46	9.16	8.11	7.78	8.48	8.9	9.88	9.47
Na ₂ O	3.87	3.82	3.69	4.03	4.19	3.19	3.01	2.64	3.83
K ₂ O	1.62	1.64	1.69	2.92	2.89	2.21	2.15	1.8	1.38
P ₂ O ₅	1.95	1.86	1.9	1.91	1.84	2.42	2.25	2.47	1.84
SO ₂	0.58	0.42	0.46	0.38	0.48	0.68	0.55	0.56	0.46
Total	98.42	98.57	98.54	97.38	97.64	97.59	97.75	98.09	98.15

Table A6 : Electron microprobe scans of plagioclase hosted melt inclusions from the Foerstner, Pantelleria balloon sample

NA018_PLG5_s2	NA018_PLG5_s3	NA018_PLG7_s1	NA018_PLG7_s2	NA018_PLG7_s3	NA018_PLG8a_s1	NA018_PLG8a_s2	NA018_PLG8a_s3	NA018_PLG8b_s1	NA018_PLG8b_s2
45.01	45.54	45.32	45.04	45.46	42.68	45.02	44.45	44.27	45.76
4.33	4.2	4.11	4.07	4.11	4.47	4.52	4.56	5.01	4.48
12.82	12.62	13.15	13.17	12.78	10.92	11.7	11.53	9.23	11.61
13.2	13.33	13.41	13.45	13.52	15.36	15.45	15.32	16.83	15
0.18	0.25	0.27	0.24	0.19	0.22	0.23	0.24	0.24	0.24
5.21	5.27	5.25	5.16	5.31	5.94	5.78	5.97	6.49	5.6
9.8	9.65	8.94	9.16	8.74	9.34	9.59	9.62	9.45	9.3
3.98	3.74	4.16	4.31	4.03	3.65	3.31	3.49	2.97	3.54
1.32	1.44	1.86	1.8	2.04	1.71	1.55	1.55	1.72	1.79
1.93	1.89	1.83	1.75	1.81	1.84	1.96	1.89	2.2	2
0.46	0.44	0.57	0.45	0.55	0.41	0.39	0.46	0.3	0.28
98.24	98.37	98.86	98.61	98.54	96.52	99.5	99.07	98.71	99.6

Table A6 continued...

NA018_PLG8b_s3	NA018_PLG9_s1	NA018_PLG9_s2	NA018_PLG9_s3	NA018_PLG10_s1	NA018_PLG10_s2	NA018_PLG10_s3	NA018_PLG11_s1	NA018_PLG11_s2
46.46	45.55	45.93	45.59	44	44.25	44.13	45.96	45.93
4.57	4.26	4.05	4.2	3.9	3.98	4.11	4.24	4.22
11.95	12.68	12.79	12.79	11.26	11.41	10.5	12.84	12.72
14.7	13.77	13.75	13.86	14.13	14.14	14.33	13.45	13.45
0.24	0.31	0.21	0.23	0.27	0.26	0.29	0.19	0.21
5.71	5.07	5.08	5.15	5.75	5.76	6.04	4.91	4.97
9.38	9.83	9.23	9.72	7.95	8.06	8.87	8.97	8.86
3.71	3.72	3.86	3.86	2.76	2.81	2.87	3.69	3.54
1.76	1.35	1.62	1.46	3.38	3.29	2.66	1.56	1.66
1.86	1.78	1.79	1.9	1.72	1.8	1.77	1.85	1.91
0.2	0.5	0.37	0.45	0.53	0.52	0.48	0.38	0.35
100.54	98.82	98.68	99.2	95.65	96.28	96.05	98.05	97.83

Table A6 continued...

NA018_PLG12_s1	NA018_PLG12_s2	NA018_PLG12_s3	NA018_PLG13_s1	NA018_PLG13_s2	NA018_PLG13_s3
43.8	43.9	43.63	45.62	45.78	45.63
4.36	4.33	4.44	4.6	4.8	4.8
11.99	12.07	11.87	12.29	12.31	12.14
15.57	15.02	15.29	14.99	15.19	15.17
0.31	0.29	0.29	0.24	0.3	0.25
5.63	5.55	5.48	5.39	5.47	5.66
9.52	9.59	9.63	9.7	9.8	9.89
3.63	3.9	3.8	3.73	3.62	3.62
1.56	1.53	1.54	1.33	1.28	1.29
1.94	1.8	1.92	1.76	1.83	1.92
0.37	0.49	0.49	0.34	0.28	0.29
98.68	98.47	98.39	99.98	100.66	100.66

Table A6 continued...

Socorro balloon sample										
Crystal ID	Soc_OLV1_s1	Soc_OLV1_s2	Soc_OLV1_s3	Soc_OLV3_s1	Soc_OLV3_s2	Soc_OLV3_s3	Soc_OLV4_s1	Soc_OLV4_s2	Soc_OLV4_s3	Soc_OLV5_s1
Glass inclusion										
SiO ₂	47.12	47.31	47.31	47.95	48.14	48.12	45.4	44.69	44.59	47.85
TiO ₂	3.5	3.44	3.43	2.84	2.92	2.75	3.82	3.6	3.56	3.09
Al ₂ O ₃	14.82	14.87	14.86	16.19	16.2	16.32	14.68	15	14.68	14.89
FeO*	10.9	10.84	11	9.8	9.67	9.77	13.55	13.48	13.58	11.11
MnO	0.17	0.19	0.24	0.13	0.18	0.12	0.22	0.2	0.25	0.16
MgO	4.99	4.97	4.71	4.72	4.76	4.66	4.78	4.79	4.81	4.92
CaO	10.1	10.06	10.35	10.76	10.77	10.78	9.79	9.6	9.47	9.72
Na ₂ O	3.59	3.56	3.63	3.34	3.47	3.48	3.34	3.25	3.5	3.45
K ₂ O	1.17	1.2	1.15	0.86	0.93	0.87	1.04	1.04	0.98	1.24
P ₂ O ₅	1.17	1.27	1.23	0.56	0.54	0.52	0.96	1	0.95	1.77
SO ₂	0.3	0.42	0.33	0.28	0.26	0.31	0.29	0.25	0.33	0.25
Total	97.82	98.13	98.25	97.43	97.85	97.71	97.88	96.9	96.71	98.45

Table A7: Electron microprobe scans of olivine hosted melt inclusions from the Socorro balloon sample

SOC_OLV5_s2	SOC_OLV5_s3	SOC_OLV6_s1	SOC_OLV6_s2	SOC_OLV6_s3	SOC_OLV7_s1	SOC_OLV7_s2	SOC_OLV7_s3	SOC_OLV8_s1	SOC_OLV8_s2
47.63	47.53	48.15	49.33	48.42	46.14	46.48	46.15	47.53	48.04
3.04	3.11	3.22	3.42	3.18	3.41	3.7	3.57	3.18	3.23
14.94	14.75	15.53	16.28	15.81	14.31	14.22	14.37	15.11	15.08
11.03	11.16	10.29	9.55	8.66	11.11	11.21	10.99	10.86	10.63
0.17	0.19	0.18	0.18	0.13	0.16	0.21	0.17	0.18	0.15
4.78	4.92	4.95	4.3	5.07	4.67	4.59	4.62	4.95	4.94
9.77	9.74	11.78	10.45	12.28	10.13	10.19	10.45	10.2	10.06
3.56	3.67	3.07	3.52	3.55	3.29	3.3	3.28	3.47	3.72
1.27	1.25	0.9	1.01	1.01	1.13	1.1	1.08	1.01	0.97
1.86	1.78	0.78	0.77	0.83	1.47	1.39	1.45	0.64	0.61
0.27	0.27	0.28	0.29	0.34	0.26	0.4	0.33	0.3	0.28
98.32	98.37	99.14	99.09	99.27	96.07	96.8	96.44	97.43	97.71

Table A7 continued...

SOC_OLV8_s3	Soc_OLV9_s1	Soc_OLV9_s2	Soc_OLV9_s3	SOC_OLV11_s1	SOC_OLV11_s2	SOC_OLV11_s3
47.77	45.91	45.98	45.82	49.5	48.94	49.67
3.23	4.85	4.75	4.91	3.72	3.33	3.51
15.21	13.84	13.88	13.88	16.34	15.72	16.52
10.8	12.23	12.3	12.16	8.83	9.79	9.13
0.17	0.25	0.21	0.23	0.13	0.15	0.09
4.96	4.98	5.06	5.05	2.45	5.73	4.4
10.21	10.61	10.61	10.48	12.09	10.29	10.33
3.76	3.44	3.34	3.28	3.9	3.56	3.65
0.99	0.96	0.99	0.94	1.04	0.89	0.95
0.65	1.29	1.32	1.29	0.72	0.64	0.6
0.29	0.37	0.45	0.27	0.31	0.27	0.27
98.04	98.73	98.89	98.33	99.04	99.3	99.11

Table A7 continued...

Socorro balloon sample												
Crystal ID	SOC_PLG1_s1	SOC_PLG1_s2	SOC_PLG1_s3	SOC_PLG2a_s1	SOC_PLG2a_s2	SOC_PLG2a_s3	SOC_PLG2b_s1	SOC_PLG2b_s2	SOC_PLG2b_s3	Soc_PLG3_s1		
Glass inclusion												
SiO ₂	47.93	48.36	48.13	49.45	49.82	50.9	50.19	49.86	50.57	47.14		
TiO ₂	3.75	3.66	3.68	3.24	3.23	3.12	3.21	3.09	2.97	3.5		
Al ₂ O ₃	14.66	14.66	14.62	14.91	15.03	15.28	14.55	14.66	14.68	14.36		
FeO*	11.9	12.06	12.11	10.72	10.78	11.01	10.77	10.79	10.85	12.04		
MnO	0.21	0.17	0.2	0.14	0.21	0.19	0.17	0.17	0.16	0.21		
MgO	4.2	4.17	4.11	4.07	4.04	3.64	4.1	4.11	4.09	4.54		
CaO	8.68	8.95	8.8	8.37	8.49	8.22	8.15	8.19	7.78	8.99		
Na ₂ O	4.17	4.02	3.98	3.97	3.99	3.7	4.12	4.1	4	4.12		
K ₂ O	1.28	1.2	1.21	1.44	1.3	1.31	1.38	1.37	1.66	1.28		
P ₂ O ₅	1.35	1.35	1.29	1.49	1.41	1.38	1.31	1.32	1.39	1.62		
SO ₂	0.36	0.43	0.43	0.26	0.24	0.22	0.29	0.18	0.28	0.4		
Total	98.46	99.02	98.56	98.06	98.56	98.97	98.25	97.84	98.43	98.2		

Table A8 : Electron microprobe scans of plagioclase hosted melt inclusions from the Socorro balloon sample

Soc_PLG3_s2	Soc_PLG3_s3	Soc_PLG6_s1	Soc_PLG6_s2	Soc_PLG6_s3	Soc_PLG7_s1	Soc_PLG7_s2	Soc_PLG7_s3	Soc_PLG7b_s1	Soc_PLG7b_s2
47.72	47.66	48.7	48.81	48.75	48.17	48.56	48.37	47.84	47.87
3.57	3.49	2.67	2.8	2.76	3.06	3.05	3.02	3.01	3.2
14.44	14.38	14.24	14.11	14.14	13.59	13.51	13.63	13.84	13.85
12.07	12.01	11.5	11.48	11.47	11.7	11.91	11.92	11.57	11.75
0.17	0.16	0.16	0.2	0.2	0.21	0.24	0.24	0.19	0.2
4.47	4.47	5.6	5.67	5.66	5.84	5.81	5.78	5.77	5.79
8.93	9.01	9.54	9.49	9.45	9.03	9.23	9.26	9.61	9.56
4.27	4.03	3.76	3.78	4	3.81	3.66	3.72	3.65	3.68
1.32	1.31	1.08	1.08	1.11	1.24	1.13	1.1	1.01	1.07
1.71	1.75	0.59	0.58	0.57	0.56	0.54	0.54	0.67	0.68
0.33	0.33	0.33	0.25	0.27	0.25	0.3	0.23	0.28	0.27
99	98.6	98.18	98.25	98.39	97.47	97.94	97.82	97.44	97.91

Table A8 continued...

Soc_PLG7b_s3	Soc_PLG8_s1	Soc_PLG8_s2	Soc_PLG8_s3	Soc_PLG9_s1	Soc_PLG9_s2	Soc_PLG9_s3	Soc_PLG10_s1	Soc_PLG10_s2	Soc_PLG10_s3	Soc_PLG11_s1	Soc_PLG11_s2	Soc_PLG11_s3
47.54	49.29	49.54	49.3	47.29	47.69	47.37	48.12	47.55	47.23	45.99	46.23	44.14
3.07	2.56	2.62	2.71	3.79	3.82	3.81	3.6	3.59	3.59	3.71	3.56	3.47
13.85	14.5	14.34	14.43	14.09	14.17	14.24	14.27	14.26	14.06	13.5	13.74	13.21
11.63	11.29	11.2	11.4	12.2	12.4	12.51	11.79	12.01	12.1	12.7	12.32	12.25
0.24	0.17	0.19	0.25	0.21	0.2	0.24	0.19	0.2	0.21	0.21	0.2	0.24
5.76	6.01	5.99	6	4.78	4.81	4.83	4.7	4.81	4.72	5.19	5.06	5.05
9.63	9.14	9.25	9.27	9.31	9.27	9.02	9.03	8.85	8.85	9.01	9.29	9.06
3.83	3.64	3.82	3.65	4.14	4.25	3.89	3.98	4.08	3.91	4.16	4.06	4.3
1.02	1.05	1.06	1.07	1.29	1.27	1.29	1.16	1.14	1.14	1.29	1.2	1.16
0.65	0.45	0.46	0.37	0.89	0.88	0.93	1.53	1.51	1.47	1.34	1.33	1.42
0.25	0.3	0.3	0.25	0.16	0.13	0.18	0.39	0.37	0.35	0.34	0.38	0.33
97.46	98.39	98.77	98.69	98.12	98.88	98.31	98.75	98.38	97.62	97.45	97.38	94.62

Table A8 continued...

<i>Host olivine composition</i>	NA018_OLV2aMI_s1	NA018_OLV2aMI_s2	NA018_OLV2aMI_s3	NA018_OLV3MI_s1	NA018_OLV3MI_s2	NA018_OLV3MI_s3	NA018_OLV5MI_s1	NA018_OLV5MI_s2
SiO2	37.95	37.98	37.95	36.8	37.18	37.74	38.35	37.83
TiO2	0.02	0.02	0.03	0.03	0.04	0.03	0.03	0.01
Al2O3	0.02	0.03	0.02	0.15	0.06	0.02	0.03	0.19
FeO*	23.97	23.8	23.97	24.1	24.31	24.05	23.7	23.99
MnO	0.37	0.34	0.38	0.39	0.38	0.38	0.36	0.41
MgO	37.65	37.87	37.78	36.84	37.07	37.52	37.77	37.81
CaO	0.26	0.26	0.26	0.28	0.27	0.26	0.27	0.27
Na2O	0.04	0	0.02	0.03	0	0.01	0.02	0.01
NiO	0.05	0.04	0.12	0.04	0.09	0.05	0.07	0
Cr2O3	0	0	0	0	0	0	0	0
Total	100.33	100.34	100.53	98.69	99.41	100.06	100.62	100.52

Table A9: Melt inclusion host crystal compositions from electron microprobe analysis

SOC_OLV1MI_s1	SOC_OLV1MI_s2	SOC_OLV3MI_s1	SOC_OLV3MI_s2	SOC_OLV3MI_s3	SOC_OLV4MI_s1	SOC_OLV4MI_s2	SOC_OLV4MI_s3	SOC_OLV4MI_s4	SOC_OLV5MI_s1	SOC_OLV5MI_s2	SOC_OLV5MI_s3
39.12	39.6	38.4	38.07	34.12	36.45	35.9	37.21	34.57	38.03	37.74	38.94
0.04	0.03	0.03	0.03	0.02	0.04	0.05	0.04	0.04	0.01	0.03	0.01
0.07	0.11	0.07	0.13	0.72	0.04	0.11	0.04	0.1	0.11	0.27	0.24
19.99	20.09	18.76	18.57	18.33	26.38	25.99	26.37	26.45	20.78	20.48	20.64
0.31	0.31	0.27	0.28	0.29	0.44	0.42	0.46	0.39	0.31	0.31	0.27
41.34	42.01	41.51	41.22	37.24	34.8	34.81	35.86	32.72	39.95	39.59	41.1
0.29	0.29	0.27	0.29	0.27	0.25	0.24	0.24	0.27	0.26	0.25	0.27
0.01	0.02	0.02	0.03	0.01	0	0	0.01	0	0.03	0.02	0
0.22	0.06	0.13	0.1	0.18	0.03	0.21	0	0.14	0.14	0.07	0.15
0.15	0.02	0	0.03	0	0.01	0.03	0.01	0.01	0.05	0.02	0.04
101.53	102.54	99.44	98.76	91.19	98.44	97.77	100.24	94.69	99.66	98.78	101.66

Table A9 continued...

SOC_OLV6MI_s1	SOC_OLV6MI_s2	SOC_OLV6MI_s3	SOC_OLV7aMI_s1	SOC_OLV7aMI_s2	SOC_OLV7bMI_s1	SOC_OLV7bMI_s2	SOC_OLV7bMI_s3	SOC_OLV8MI_s1	SOC_OLV8MI_s2
37.91	38.29	38.16	39.79	38.98	38.9	38.51	35.05	40.39	39.69
0.02	0.03	0.01	0.03	0.04	0.03	0.04	0.04	0.03	0.03
0.03	0.02	0.04	0.1	0.04	0.03	0.08	0.51	0.28	0.11
18.35	18.37	18.36	19.98	20.45	20.39	20.3	20.34	20.08	20.26
0.26	0.28	0.28	0.3	0.32	0.28	0.33	0.33	0.31	0.31
40.95	41.41	41.3	41.17	41.41	41.08	40.36	35.18	42.66	42.24
0.24	0.26	0.25	0.25	0.27	0.26	0.26	0.27	0.28	0.26
0	0.02	0.01	0.03	0	0	0.01	0.04	0	0.04
0.16	0.07	0.27	0.17	0.07	0.05	0.02	0.13	0.21	0.25
0.03	0.03	0.04	0	0	0.01	0	0	0.06	0.04
97.95	98.77	98.71	101.82	101.59	101.03	99.9	91.89	104.3	103.22

Table A9 continued...

SOC_OLV8MI_s3	SOC_OLV9MI_s1	SOC_OLV9MI_s2	SOC_OLV9MI_s3	SOC_OLV11MI_s1	SOC_OLV11MI_s2
37.62	30.64	38.44	34.28	39.98	37.34
0.04	0.05	0.02	0.09	0.02	0.01
0.07	0.3	0.05	0.43	0.08	0.41
20.13	21.47	21.58	21.07	18.85	18.8
0.32	0.32	0.32	0.3	0.26	0.26
40.86	31.13	40.13	35.04	42.91	38.67
0.27	0.25	0.25	0.32	0.26	0.27
0	0.01	0.01	0.04	0.01	0.02
0.15	0.03	0.11	0.19	0.26	0.14
0.01	0.05	0	0.06	0	0.11
99.46	84.25	100.9	91.82	102.62	96.01

Table A9 continued...

Sample Name	Density g/cm ³	e 3530	e 1430, 1515 Thickness (mm)	Test	3530	1430	1515	
NA018-OLV1a	3.01	63.00	315.46	0.102	test-1	1.457	0.106113	0.073788
					test-2	1.783	0.127884	0.102225
					test-3	1.146	0.063201	0.027415
					test-4	1.45	0.104342	0.04599
					test-5	1.277	0.080015	0.055015
NA018-OLV1b	3.01	63.00	315.46	0.102	test-1	0.964	0.112347	0.083477
					test-2	0.951	0.126385	0.101403
					test-3	0.986	0.090172	0.056909
					test-4	1.122	0.109018	0.081281
					test-5	1.035	0.107034	0.078246
NA018-OLV2a	3.01	63.00	315.46	0.04	test-1	0.409	0.152938	0.195698
					test-2	0.42	0.150069	0.179203
					test-3	0.412	0.140705	0.171527
					test-4	0.403	0.121717	0.172391
					test-5	0.398	0.146783	0.179577
NA018-OLV2b	3.01	63.00	315.46	0.04	test-1	0.163	0.032485	0.008545
					test-2	0.155	0.031828	0.020697
					test-3	0.171	0.018983	-0.00536
					test-4	0.148	0.023024	0.003139
					test-5	0.152	0.022742	0.006933
NA018-OLV3	3.01	63.00	317.57	0.079	test-1	0.877	0.200705	0.21731
					test-2	0.928	0.203214	0.218257
					test-3	0.932	0.190535	0.210278
					test-4	0.92	0.189685	0.203932
					test-5	0.91	0.190494	0.207828
NA018-OLV5	3.04	63.00	316.31	0.014	test-1	0.154	0.088795	0.176767
					test-2	0.174	0.077824	0.20721
					test-3	0.125	0.068671	0.181223
					test-4	0.199	0.069876	0.168975
					test-5	0.152	0.095968	0.214813
NA018-OLV8	3.08	63.00	308.60	0.054	test-1	0.457	0.020862	0.014661
					test-2	0.42	0.001859	0.002786
					test-3	0.408	0.008772	0.006756
					test-4	0.462	0.007955	0.010044
					test-5	0.489	0.001103	-0.00379
NA018-CPX1	3.01	63.00	303.48	0.08	test-1	0.658	0.150589	0.16431
					test-2	0.735	0.153962	0.175022
					test-3	0.783	0.140091	0.156167
					test-4	0.77	0.14426	0.158172
					test-5	0.724	0.140269	0.155575

Table A10: Sample data collected from FTIR analysis used to calculate volatile contents of melt inclusion from olivines and a clinopyroxene within the Foerstner, Pantelleria balloon sample.

Sample Name	Density g/cm ³	e 3530	e 1430, 1515 Thickness (mm)	Test	3530	1430	1515	
NA018-PLG1	3.03	63.00	306.18	0.133	test-1	0.516	0.008571	-0.00766
					test-2	0.457	0.006277	-0.00438
					test-3	0.48	-0.00919	-0.02112
					test-4	0.416	-0.00972	-0.01983
					test-5	0.513	-0.00884	-0.0225
NA018-PLG2	3.02	63.00	285.64	0.057	test-1	0.445	0.004393	-0.01269
					test-2	0.577	0.016695	-0.13213
					test-3	0.603	0.027843	-0.01799
					test-4	0.678	0.000453	-0.02748
					test-5	0.663	0.000974	-0.03855
NA018-PLG3	3.20	63.00	324.52	0.07	test-1	0.298	-0.01804	-0.01178
					test-2	0.252	-0.01867	-0.01629
					test-3	0.291	-0.01925	-0.0182
					test-4	0.267	-0.0202	-0.01619
					test-5	0.272	-0.02154	-0.01954
NA018-PLG4	3.20	63.00	324.52	0.053	test-1	0.449	0.055894	-0.18403
					test-2	0.376	0.043417	-0.23437
					test-3	0.338	0.016085	-0.18818
					test-4	0.386	0.100457	-0.1709
					test-5	0.376	0.052405	-0.20109
NA018-PLG5	3.03	63.00	307.52	0.059	test-1	0.294	0.021328	0.008507
					test-2	0.291	0.019191	0.001296
					test-3	0.239	0.004829	-0.00303
					test-4	0.243	-0.01816	-0.03637
					test-5	0.276	-0.00228	-0.01556
NA018-PLG6	3.03	63.00	307.52	0.083	test-1	0.789	0.077871	-0.80613
					test-2	0.62	0.07204	-0.81586
					test-3	0.625	0.076088	-0.84174
					test-4	0.557	-0.00627	-0.67729
					test-5	0.997	0.085748	-0.89268
NA018-PLG7	3.01	63.00	294.59	0.059	test-1	0.833	0.063396	-0.00619
					test-2	0.818	0.070114	-0.00245
					test-3	0.931	0.062423	-0.01022
					test-4	0.725	0.054859	-0.0185
					test-5	0.674	0.053571	-0.02613
NA018-PLG8a	3.09	63.00	314.73	0.047	test-1	0.154	0.008959	-0.01243
					test-2	0.103	0.021734	-0.03457
					test-3	0.111	-0.01877	-0.02745
					test-4	0.149	0.010395	-0.00771
					test-5	0.129	0.000342	-0.01616
NA018-PLG8b	3.09	63.00	315.34	0.047	test-1	0.139	0.003157	-0.01437
					test-2	0.128	0.000443	-0.02537
					test-3	0.091	-0.00226	-0.03095
NA018-PLG9a	3.03	63.00	307.92	0.086	test-1	0.22	-0.02138	-0.01262
					test-2	0.177	-0.01799	-0.00798
					test-3	0.179	-0.02575	-0.023
					test-4	0.185	-0.02481	-0.02134
					test-5	0.204	-0.02574	-0.02288
NA018-PLG9b	3.03	63.00	307.92	0.086	test-1	0.319	-0.00543	0.004455
					test-2	0.547	0.004434	-0.00727
					test-3	0.703	0.013472	-0.02232
					test-4	0.515	0.001938	-0.01317
					test-5	0.657	0.004494	-0.01658
NA018-PLG10	3.04	63.00	320.91	0.07	test-1	0.122	0.013361	0.008073
					test-2	0.105	0.009029	-0.00764
					test-3	0.142	0.009348	-0.00576
					test-4	0.125	0.005798	-0.00798
					test-5	0.1	0.006249	-0.00646

Table A11: Sample data collected from FTIR analysis used to calculate volatile contents of melt inclusion from plagioclase within the Foerstner, Pantelleriaoon sample.

NA018-PLG11b	3.02	63.00	306.25	0.049	test-1	0.304	0.016389	0.029555
					test-2	0.324	0.017561	0.030385
					test-3	0.372	-0.0033	0.024819
					test-4	0.417	-0.00073	0.023589
					test-5	0.303	0.000147	0.01292
NA018-PLG12	3.08	63.00	308.60	0.087	test-1	0.221	0.031029	0.04377
					test-2	0.197	0.036254	0.046277
					test-3	0.212	0.025539	0.033437
NA018-PLG13	3.08	63.00	313.12	0.075	test-1	0.348	0.26942	0.252751
					test-2	0.51	0.003545	-0.07401
					test-3	0.59	0.014465	-0.04232
					test-4	0.474	0.026718	-0.01571
					test-5	0.489	0.012251	-0.04133

Table A11 continued...

Sample Name	Density g/cm ³	e 3530	e 1430, 1515	Thickness (mm)	Test	3530	1430	1515
SOC-OLV1	2.93	63.00	317.61	0.053	test-1	0.417	0.184438	0.19262
					test-2	0.41	0.185023	0.193108
					test-3	0.464	0.173945	0.183916
					test-4	0.451	0.170606	0.179074
					test-5	0.397	0.169895	0.179522
SOC-OLV2	2.93	63.00	317.61	0.041	test-1	0.403	0.3231	0.334864
					test-2	0.41	0.30496	0.330838
					test-3	0.378	0.294965	0.329058
					test-4	0.376	0.296766	0.326002
					test-5	0.381	0.296931	0.328839
SOC-OLV3	2.88	63.00	325.96	0.054	test-1	0.523	0.316012	0.346908
					test-2	0.438	0.298811	0.329594
					test-3	0.0528	0.306338	0.338266
					test-4	0.537	0.314864	0.34717
					test-5	0.533	0.305667	0.33755
SOC-OLV4a	3.00	63.00	318.47	0.049	test-1	0.446	0.160352	0.139572
					test-2	0.401	0.165343	0.174947
					test-3	0.405	0.161399	0.144324
					test-4	0.411	0.176003	0.170219
					test-5	0.421	0.165687	0.170181
SOC-OLV4b	3.00	63.00	318.47	0.049	test-1	0.077	0.084345	0.026863
					test-2	0.252	0.099481	0.077135
					test-3	0.261	0.130636	0.088331
					test-4	0.238	0.087264	0.061899
					test-5	0.258	0.12986	0.121304
SOC-OLV5	2.91	63.00	314.88	0.165	test-1	1.551	0.169957	0.180642
					test-2	1.599	0.170787	0.180132
					test-3	1.625	0.155333	0.165658
					test-4	1.608	0.155512	0.165772
					test-5	1.596	0.151219	0.15962
SOC-OLV6	2.90	63.00	332.28	0.021	test-1	0.239	0.208489	0.235533
					test-2	0.225	0.100282	0.157859
					test-3	0.243	0.1866	0.241797
SOC-OLV7a	2.95	63.00	325.39	0.042	test-1	0.365	0.238517	0.149639
					test-2	0.372	0.233293	0.177625
					test-3	0.275	0.212345	0.087691
					test-4	0.347	0.21929	0.164183
					test-5	0.276	0.309179	0.039055
SOC-OLV7b	2.95	63.00	325.39	0.042	test-1	0.366	0.162397	0.128315
					test-2	0.358	0.157075	0.122874
					test-3	0.372	0.15289	0.12908
					test-4	0.364	0.155015	0.121339
					test-5	0.356	0.168734	0.142094
SOC-OLV8	2.92	63.00	316.23	0.067	test-1	0.662	0.285626	0.31097
					test-2	0.673	0.277022	0.303343
					test-3	0.72	0.283664	0.311945
					test-4	0.644	0.285623	0.312414
					test-5	0.656	0.285	0.31225
SOC-OLV9	3.03	63.00	326.24	0.05	test-1	0.499	0.170325	0.186889
					test-2	0.488	0.194652	0.20698
					test-3	0.534	0.179228	0.194415
					test-4	0.529	0.184882	0.197323
					test-5	0.492	0.173092	0.194082
SOC-OLV10	3.03	63.00	326.24	0.043	test-1	0.426	0.157417	0.122049
					test-2	0.436	0.162092	0.119839
					test-3	0.412	0.159456	0.138297
SOC-OLV11a	2.89	63.00	320.81	0.076	test-1	0.255	0.08126	0.099404
					test-2	0.26	0.076504	0.097334
					test-3	0.184	0.076589	0.093993
					test-4	0.243	0.074526	0.088934
					test-5	0.296	0.073068	0.086374
SOC-OLV11b	2.89	63.00	320.81	0.076	test-1	0.15	0.057082	0.059773
					test-2	0.168	0.06573	0.067735
					test-3	0.134	0.053601	0.053761
					test-4	0.119	0.051138	0.055607
					test-5	0.137	0.043821	0.046051

Table A12: Sample data collected from FTIR analysis used to calculate volatile contents of melt inclusion from olivines within the Socorro balloon sample.

Sample Name	Density g/cm ³	e 3530	e 1430, 1515	Thickness (mm)	Test	3530	1430	1515
SOC-PLG1a	2.94	63.00	295.55	0.063	test-1	0.577	0.152749	0.155989
					test-2	0.611	0.158264	0.159427
					test-3	0.559	0.147918	0.149446
					test-4	0.602	0.151095	0.156658
					test-5	0.55	0.147636	0.15567
SOC-PLG1b	2.94	63.00	295.55	0.063	test-1	0.558	0.168138	0.182961
					test-2	0.571	0.17	0.187541
					test-3	0.564	0.154131	0.175204
					test-4	0.621	0.163374	0.17376
					test-5	0.576	0.154687	0.169472
SOC-PLG1c	2.94	63.00	295.55	0.063	test-1	0.535	0.160669	0.172751
					test-2	0.492	0.15229	0.163763
					test-3	0.502	0.151718	0.165977
					test-4	0.566	0.148178	0.16012
					test-5	0.464	0.127716	0.146151
SOC-PLG2a	2.88	63.00	294.74	0.143	test-1	0.25	-0.01208	0.003053
					test-2	0.203	-0.01907	-0.008
					test-3	0.231	-0.00799	0.002194
					test-4	0.175	-0.01687	0.002053
					test-5	0.258	-0.01875	0.002219
SOC-PLG2b	2.88	63.00	294.74	0.143	test-1	0.641	0.002261	0.001106
					test-2	0.619	-0.00841	0.009269
					test-3	0.714	-0.0038	0.00351
					test-4	0.666	-0.00699	0.001148
					test-5	0.757	-0.00494	0.005511
SOC-PLG3	2.94	63.00	295.42	0.116	test-1	0.742	0.175624	0.188498
					test-2	0.854	0.190267	0.203249
					test-3	0.719	0.17324	0.189313
					test-4	0.804	0.160058	0.173659
					test-5	0.82	0.166799	0.182834
SOC-PLG4a	2.94	63.00	295.42	0.044	test-1	0.463	0.095559	-0.0746
					test-2	0.476	0.106626	-0.0333
					test-3	0.509	0.117711	-0.07867
					test-4	0.5	0.106092	-0.07133
					test-5	0.456	0.106004	-0.07717
SOC-PLG4b	2.94	63.00	295.42	0.044	test-1	0.481	0.414324	0.277694
					test-2	0.448	0.422437	0.287676
					test-3	0.495	0.415676	0.28051
					test-4	0.463	0.407115	0.269982
					test-5	0.471	0.408905	0.274121
SOC-PLG5	2.94	63.00	295.42	0.077	test-1	0.477	0.126951	0.156791
					test-2	0.506	0.129912	0.16895
					test-3	0.505	0.094251	0.118915
					test-4	0.574	0.12738	0.156986
					test-5	0.516	0.129801	0.153316
SOC-PLG6	2.90	63.00	306.32	0.078	test-1	0.668	0.054084	0.049246
					test-2	0.653	0.049951	0.046832
					test-3	0.669	0.049408	0.048348
					test-4	0.699	0.054018	0.049712
					test-5	0.684	0.052751	0.047743
SOC-PLG7a	2.93	63.00	306.03	0.111	test-1	0.469	0.106632	0.121788
					test-2	0.451	0.092213	0.105403
					test-3	0.402	0.072784	0.087038
					test-4	0.381	0.070004	0.08528
					test-5	0.508	0.095441	0.110046
SOC-PLG7b	2.93	63.00	310.03	0.111	test-1	0.649	0.081253	0.089924
					test-2	0.652	0.085229	0.093778
					test-3	0.648	0.080262	0.091333
					test-4	0.65	0.07798	0.087879
					test-5	0.643	0.077906	0.087547
SOC-PLG8	2.89	63.00	307.05	0.105	test-1	0.951	0.315033	0.341678
					test-2	0.929	0.29892	0.325934
					test-3	0.958	0.306618	0.336116
					test-4	0.955	0.295011	0.323803
					test-5	0.947	0.300678	0.330095

Table A13: Sample data collected from FTIR analysis used to calculate volatile contents of melt inclusion from plagioclase within the Socorro balloon sample.

SOC-PLG9a	2.96	63.00	298.46	0.058	test-1	0.262	0.032426	-0.09941
					test-2	0.241	0.026907	-0.09978
					test-3	0.299	0.043845	-0.09981
					test-4	0.233	0.025049	-0.10583
					test-5	0.236	0.029214	-0.10079
SOC-PLG9b	2.96	63.00	298.46	0.058	test-1	0.264	0.032426	-0.09941
					test-2	0.27	0.026907	-0.09978
					test-3	0.248	0.043845	-0.09981
					test-4	0.222	0.025049	-0.10583
					test-5	0.298	0.029214	-0.10079
SOC-PLG9c	2.96	63.00	298.46	0.058	test-1	0.266	0.032426	-0.09941
					test-2	0.256	0.026907	-0.09978
					test-3	0.235	0.043845	-0.09981
					test-4	0.15	0.025049	-0.10583
					test-5	0.204	0.029214	-0.10079
SOC-PLG10	2.95	63.00	297.91	0.043	test-1	0.384	0.138156	0.140342
					test-2	0.414	0.144186	0.147148
					test-3	0.371	0.139616	0.143616
SOC-PLG11	2.98	63.00	296.08	0.141	test-1	0.934	0.158276	0.175685
					test-2	0.993	0.149642	0.166883
					test-3	0.912	0.138711	0.154811

Table A13 continued...

Sample Name	Density g/cm ³	e 3530	e 1430, 1515 Thickness (mm)	Test	3530	1430	1515	
NA018_GL1	3.01	63.00	300.89	0.132	test-1	0.201	0.024356	0.007793
					test-2	0.229	0.022506	0.00924
					test-3	0.219	0.044256	-0.02225
					test-4	0.228	-0.00251	-0.00639
					test-5	0.199	0.020535	-0.01063
NA018_GL2	3.02	63.00	310.21	0.157	test-1	0.181	0.055124	0.021392
					test-2	0.156	0.016397	0.020156
					test-3	0.334	0.006509	-0.00678
					test-4	0.259	-0.00178	-0.00138
					test-5	0.305	0.002762	-0.00564
NA018_GL3	3.02	63.00	316.45	0.136	test-1	0.308	0.01132	-0.00641
					test-2	0.256	0.00841	0.010671
					test-3	0.269	0.000554	-4.9E-05
SOC_GL1	2.96	63.00	303.23	0.218	test-1	0.572	-0.00826	-0.01017
					test-2	0.763	0.034506	0.000898
					test-3	0.693	0.002506	-0.0043
					test-4	0.697	0.070059	-0.02839
					test-5	0.617	0.025656	-0.04787
SOC_GL2	2.97	63.00	305.43	0.141	test-1	0.67	0.020053	0.011811
					test-2	0.684	0.025437	0.00645
					test-3	0.682	0.004334	-0.00239
					test-4	0.676	0.004805	-0.0015
					test-5	0.681	0.003425	-0.00131
SOC_GL3	2.97	63.00	303.38	0.127	test-1	0.533	0.015294	0.010229
					test-2	0.567	0.017663	0.010649
					test-3	0.569	0.008388	-0.00096
					test-4	0.583	0.006278	0.000667
					test-5	0.606	0.005539	-0.002

Table A14: Sample data collected from FTIR analysis used to calculate volatile contents of matrix glass from the Foerstner, Pantelleria and Socorro balloon samples.