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Solid Earth
Discussions

Interactive comment on "First experimental evidence for the CO_2-driven origin of Stromboli's major explosions" *by* A. Aiuppa et al.

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Authors' reply to Interactive comment on "First experimental evidence for the CO2-driven origin of Stromboli's major explosions" by A. Aiuppa et al. Anonymous Referee #2

Specific comments Title: I am not sure that "experimental" is the correct word for the title; would "observational" be better?

Authors' reply: We accept the reviewer invitation to change the title.

Figures 2, 3, 4: the authors state the accuracy of the CO2 flux measurements as _40%. What is the precision? I would imagine considerably better, but a detailed treatment of it is absolutely necessary for this paper given the emphasis on interpreting changes

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and variability in the CO2 flux.

Authors' reply: We evaluate - from analysis of data taken within individual days - that precision of our calculated CO2 fluxes is $\leq$20%. The text will be revised accordingly.

Page 418, top: the prediction that the magnitude of the explosion should be proportional to the enhanced degassing rate prior to the explosion (Allard, 2010) could be tested using this dataset. Is there a relationship between the mass of CO2 accumulated/ leaked and the seismic energy released by the explosion perhaps, or some measure of erupted volume? Likewise is there a correlation between the time frame for accumulation and leakage, and the magnitude of the explosion? These kinds of analyses would lend support to a gas accumulation model.

Authors' reply: The message here is that the CO2 flux increase we measured prior to one paroxysmal explosion (on 15 March 2007) was by far larger (factor 10) than all CO2 flux increases precursory to the major (milder) explosions that occurred in 2008-2010. If we focus on the dataset for those major explosions (i.e., excluding the March 2007 paroxysm), we find no simple correlation between the accumulated CO2 mass and the explosion features. We first compared the accumulated CO2 mass vs. the syn-explosive seismic displacement and tilt for each explosion, but found no obvious correlation. Secondly, the volume of materials erupted during major explosions is either unknown or poorly quantified (for a few events), thereby precluding any quantitative analysis. Finally, there is no straightforward relationship between the magnitude of each explosion and the precursory time interval for gas accumulation and leakage: the frequent clustering of more than 1 major explosion in relatively short interval – days/weeks - suggests that foam empting could occur in several steps and that complete foam exhaust would be achieved through successive events. This makes a more complex scenario, in which foam growth, collapse and emptying may be controlled by factors other than simply the volume of accumulated gas. To conclude, more observations and data are still required in order to establish a quantitative relationship between the magnitude of each explosion, the volumes of erupted gas and magma, the length of

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pre-eruptive intervals, the amount of accumulated CO2, and the physical processes of bubble foam growth/empting. We plan to clarify this point by reworking the paragraph at page 418 when submitting our final manuscript files. .

Page 419: the observation that mass balance is satisfied by the CO2 degassing patterns strikes me as absolutely crucial but at the same time, I do not see why foam accumulation is the only way that this criterion can be satisfied. Surely magma accumulation and ensuing pressure changes interacting with a storage system could reproduce such changes? Has this been explored in detail? Such behaviour has been observed in silicic systems and is consistent with a model of pressurisation and non-linear magma flow, proposed by Slezin, Melnik and co-workers.

Authors' reply: We acknowledge the above comment and do not discard the possibility that non-linear magma flow (e.g. Melnik & Sparks 1999, 2002; Slezin 2003) or/and a variable magma supply rate (and pressurization conditions) could also account for (or contribute to) the observed CO2 degassing patterns. However, owing to the insular position of Stromboli - whose only the upper cone emerges from the Tyrrhenian Sea - the data currently at hand (e.g. seismic, geodetic, petrologic) hardly allow a quantitative assessment of that possibility. Instead, several observations strongly argue in support of a key role of differential gas transfer and bubble foam processes at this volcano: (i) the long-lived and quite steady periodicity of CO2-enriched Strombolian explosions (compared to the passive degassing; Burton et al. 2007), which are typically driven by CO2-rich gas slugs, (ii) the time-averaged budgets of gas and magma showing that less than one tenth of the supplied basalt is actually erupted (Allard et al. 2008), (iii) the constant SO2 emission rate in the two years investigated (our Figure 4), as well as petrologic data (e.g. Métrich et al. 2008), which both indicate a rather steady magma supply rate (at that time scale at least), and (iv) the gradual spectrum in frequency and energy of the explosions at Stromboli (the most frequent ones being the least powerful, and reciprocally), which strongly suggests some common CO2-rich gas or gas-melt trigger (Allard 2010; Aiuppa et al. 2010). Clearly, numerical modelling is definitely required (and in course) for better quantifying the potential relationship between our observations of CO2 flux increases prior to the major explosions and the processes of bubble foam growth, leakage and emptying.

Page 421: it is indeed interesting that much of the CO2 release for the paroxysmal events could occur prior to the main explosive event. This would be consistent with explosive events at Kilauea and elsewhere however, where the shallow magma acceleration is caused by H2O degassing, in the manner proposed by Wilson, Head, Parfitt and co-workers in several publications. Perhaps CO2 provides an initial impetus and H2O takes over at low pressures?

Authors' reply: It is definitely agreed that H2O contributes to low P degassing, but most likely during/shortly before explosions rather than days before (as for CO2). During ordinary Strombolian activity, H2O loss at Stromboli drives crystallization of the deeply arising magma and its change into the shallow crystallized (>45%) scoria-producing magma typically erupted during Strombolian explosions. During major explosions/paroxysms, however, the deep magma is erupted virtually aphyiric (<5% crystals); it is therefore unlikely that extensive H2O loss occurs long before these events. Prior to these large-scale events the aphyric magma rises at a fast rate (possibly in a few hours from the ∼7 km deep reservoir; Métrich et al., 2005; Pino et al. 2011), thus making H2O degassing an essentially syn-eruptive feature (and ultimately preventing magma crystallisation).

Technical corrections Page 412, line 24: "open-vent" delete last "s" Page 414, line 11: delete "top of" Page 418, line 21: change to "for most of the volcanic gas discharge" Line 23: change to "whose fast ascent, followed by bursting, drive the"

Authors' reply: all technical corrections will be dealt with upon submission of the final manuscript files for possible publication on SE

Interactive comment on Solid Earth Discuss., 3, 411, 2011.