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Solid Earth
Discussions

Interactive comment on "Estimating the depth and evolution of intrusions at resurgent calderas: Los Humeros (Mexico)" *by* Stefano Urbani et al.

Stefano Urbani et al.

stefano.urbani@uniroma3.it

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We thank the Referee for her comments that stimulated to expand and better explain the outcome of the analogue models. The results of the analogue models are now presented more clearly and benefit of additional data. The introduction has been rewritten and a subsection with the interpretation of the analogue modeling results has been added in the discussion. A "bold" text copy of the manuscript (where all the minor changes and improvements with regard to the previous version, except the removed parts, are in red bold) is attached to this reply as a supplement.

Below are the replies to all the general points raised by the referee:

COMMENT: (1). Introduction should be reworked to better present caldera resurgence

References are missing in the introduction. Important articles related to caldera resurgence should be cited at the beginning. Smith and Bailey (1968) and Lipman (1984) are two key literature review papers that should be referred to when defining resurgence and its main characteristics.

REPLY: We added the references suggested by the referee in the introduction (lines 33-35 of the revised "bold" manuscript).

COMMENT: When it comes to the magmatic origin of resurgence, it is not a resolved question yet, as hydrothermal systems are also important sources of deformation in calderas and as different processes and timescales overlap in post-collapse caldera deformation. This complexity should be mentioned and a few arguments in favor of the magmatic origin should be given (such as large amplitudes and long timescales of the uplift, magmatic intrusions found in old eroded resurgent calderas).

REPLY: We followed the referee's suggestion documenting all the processes that are thought to trigger resurgence (lines 35-42 of the revised "bold" manuscript).

COMMENT: "It is attributed to the emplacement of silicic magma". I have reasons to believe that resurgence also happens in basaltic environments even if it is not documented yet (article in preparation on a caldera in Galapagos). Additionally, resurgence is often associated with the injection of more primitive (then more mafic) magma (see references in a paper you cited: Brothelande et al., 2016, P.2, end of the first paragraph).

REPLY: We changed the text specifying that resurgence is commonly attributed to the ascent of silicic magma but, though rare, may be also due to the ascent of more primitive magma as recently documented in Alcedo (lines 43-47 of the revised "bold" manuscript).

COMMENT: When mentioning uplift styles and rates of natural resurgence, give specific natural examples (and associated references).

REPLY: This has been done (lines 61-68 of the revised "bold" manuscript).

COMMENT: A short description of the morphology of resurgent structures should be given, so the reader could be able to compare Los Potreros resurgent dome to other examples, and know if it has a typical or atypical morphology. Most resurgent domes are elongated and host one (or several) longitudinal graben at the top (See for instance Fig. 1 of Brothelande et al., 2016). Can circular domes can be considered as less common in nature?

REPLY: We added a short description of the morphology of some examples of resurgent domes (lines 47-51 of the revised "bold" manuscript). Sub-circular domes have been reported at Long Valley (Hildreth et al., 2017), Cerro Galan (Folkes et al., 2011), Grizzly Peak (Fridrich et al., 1991) with both longitudinal graben (Long Valley) or concentric fault blocks (Grizzly Peak) at the top. Despite being less common, we show that the shape of the dome (i.e. elliptical or sub-circular) and/or of the apical graben/depression (i.e. longitudinal or concentric) has no influence on the inferred depth of intrusion (see the revised Discussion section and analogue modeling results).

COMMENT: L. 53-55 - Confusing sentence: "with resurgence within the innermost...due to the uplift of a resurgence due to...". Please reformulate. Additionally "commonly" seems incorrect in this context.

REPLY: We changed "commonly" with "previously" and rewritten the sentence so that it should be clearer now (lines 75-78 of the revised "bold" manuscript).

COMMENT: (2). Analogue modelling should be revised L. 143 : incorrect use of term "respectively".

REPLY: This has been deleted.

COMMENT: Figure 2 should be better designed: it does not show how the silicone intrudes the sand pack. Caption can be completed as well.

REPLY: We have redrawn fig. 2 (now figure 3 in the revised manuscript) which now

shows that the silicone intrudes the sand pack from its base and completed the caption (lines 588-590 of the revised "bold" manuscript).

COMMENT: I would not use the term graben to designate the crestal depression that develops at the apex of a circular tectonic dome: a graben is generally a depressed block of the crust bordered by parallel faults.

REPLY: We changed the term "graben" with "apical depression" where necessary.

COMMENT: A very small number of experiments were conducted: 3. This is far to be enough to be representative and reliable. How are experiments 4 and 5 different in terms of initial conditions? It seems there is only two sets of different initial conditions.

REPLY: We thank the reviewer for this comment. As now shown in table 3 we performed 5 experiments testing three different values of the overburden thickness (T= 10, 30 and 50 mm) and replicating some experiments to ensure their reproducibility and reliability (experiments 1 and 2 and experiments 3 and 4 now specified in the revised text, see lines 259-261 of the revised "bold" manuscript). Since no difference is observed in the replicated experiments, we show only the three representative ones for each value of T. Please note that we changed the labeling of the experiments so that they appear numbered in series now (see also reply to referee J. Cole).

COMMENT: Two additional concerns arise from there: The sand pack thickness T is considered as the only unknown variable. Unless it is properly justified, the source diameter D is also unknown, and should be varied. D is commonly considered as a variable in experiments, that show a high relevance of the T/D ratio.

REPLY: We agree with the reviewer comment. One of the findings of our paper is that the linear relationship between the graben (or apical depression in our case) width and the overburden thickness found in Brothelande and Merle 2015 is confirmed for sub-circular sources thus we are interested to investigate resurgent domes. Therefore, testing different source diameters so that T/D $\sim$ 1 is not useful for our purposes as we

would have obtained resurgent blocks and no apical depression would have formed as shown by (Acocella et al., 2001). Despite it would be interesting to see if the tested relationship is affected by the source diameter (but still in the resurgent domes regime), we believe that the new findings of this paper are still interesting and stimulating for future experimental works on this topic.

COMMENT: The authors claim they evidence a linear relationship between Lg and T (L.257 – Fig. 7): how can a relationship be inferred from only two points?

REPLY: With the new added experiments to the dataset, we believe that 5 experiments are enough to confirm the linear relationship between Lg and T for sub-circular domes.

COMMENT: I am very confused by the author's choice of model geometries. This manuscript present experiments of circular shaped domes with circular depressions in order to interpret an elongated dome with a longitudinal graben (Loma Blanca bulge). Why?

REPLY: One of the aims of our paper is to test the validity of relationship found by Brothelande and Merle 2015 for circular domes. This is particularly useful for the Los Potreros case study showing both sub-circular (Arroyo Grande) and elliptical (Loma Blanca) bulges. Therefore, having demonstrated that the tested relationship is independent from the source eccentricity, we use our results to estimate the intrusion depth of the Loma Blanca bulge. More in general, we would like to stress that it is the basic deformation pattern which matters, which is independent of any elongation of the structure, which represents only a minor complication of the basic pattern (e.g. Roche et al., 2000).

COMMENT: Then, they rely on Brothelande and Merle (2015) to complete their results interpretation and Tt calculation. However, the geometry of models are different: Brothelande and Merle study elongated sources with linear grabens. Is this exactly comparable?

REPLY: This is one of the new findings of our paper. Our results show that the theoretical equation for the calculation of Tt found in Brothelande and Merle 2015 with elliptical sources is still applicable for subcircular sources so it is independent form its eccentricity. Indeed, the percentage difference between T and Tt (see table 4) can be considered as a first order approximation of the source depth of resurgent domes, despite any eccentricity and shape of the apical extensional structures (i.e. linear grabens or sub-circular depressions).

COMMENT: On the other hand, previous analogue models of circular intrusion-related domes have been performed, some of which showing crestal depressions and radial extension patterns as in the authors experiments. However, they are very poorly referenced: Acocella et al., 2001; Walter and Troll, 2001; Marti et al., 1994; Galland et al., 2009, etc.

REPLY: We warmly thank the reviewer for this comment and we apologize for the poor referencing. The suggested papers have been cited in a new subsection of the discussion (see the new subsection 5.1).

COMMENT: Please recall more clearly what were the main conclusions of resurgence analogue experiments, and how the new experiments in this manuscript were designed to complete these studies.

REPLY: We have now better specified our conclusions and the rationale of the analogue experiments (lines 80-82; 84-86; 167-169; 279-298; 396-397 of the revised "bold" manuscript).

Sincerely,

The Corresponding Author

Stefano Urbani

Please also note the supplement to this comment:

https://www.solid-earth-discuss.net/se-2019-100/se-2019-100-AC2-supplement.pdf

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2019-100, 2019.