Response to reviewers

Reviewer Comments to Author:  
  
Reviewer: 1  
  
Comments to the Author  
Manuscript ID: JPET-Apr-24-0074  
  
Title: Depths in a day - A new era of rapid-response Raman-based barometry using fluid-inclusions  
Authors: Charlotte L. DeVitre, Penny E. Wieser, Alex Bearden, Raela Richie, Berenise Rangel, Matthew Gleeson, John Grimsich, Kendra Lynn, Drew Down, Natalia Deligne and Katie Mullike  
  
General comments:  
This manuscript reports the application of Raman-based fluid inclusion geobarometry to fluid inclusions in olivine erupted from recent Kilauea volcano activity. The authors successfully estimated the magma chamber depth rapidly. The primary conclusion is that this method provides estimations of magma chamber depth in a relatively short time compared to geobarometers based on the major element chemistry of minerals or the volatile composition of melt inclusions. However, since the authors did not develop innovative technology that allows for such rapid measurement, these results may be modest for publication in the Journal of Petrology.

We thank the reviewer for their thorough work. While we did not develop technology in this contribution, we did develop the tools necessary as well as demonstrated the reliability of the technique in two previous contributions (Wieser and DeVitre (2024) in J.Volcanica, and DeVitre and Wieser (2024) in Geochemical Perspective Letters). We emphasize that the purpose of this study was to demonstrate through a rigorous simulation in a low-risk scenario that the method is now viable and fast enough to be used as a monitoring tool. This had not been demonstrated previously. These were also the reasons why we originally chose a Letter format.   
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This was an issue with the scale, it is fixed.

Specific comments:  
L25-29: This sentence does not specify which concerns are addressed by this study. As a result, readers cannot discern what specific issues were resolved. Please elaborate on the specific concerns that were mitigated by your research.  
  
L51-52: After thoroughly reviewing Re et al. (2021), I could not find any mention of storage depth estimation taking several months to years using melt inclusion geobarometry. Could you specify the source of this information?  
  
L51-52: While I agree that estimating storage depths based on volatile content analysis takes longer than Raman-based FI geobarometry, suggesting it takes several months to years seems exaggerated. If a team with access to SIMS and Raman spectroscopy equipment prioritizes sample preparation and analysis, the process could be completed within one week to one month.  
  
L51-58: CO2 fluid inclusion geobarometry using microthermometry has been applied to peridotite and phenocrysts since at least the 1980s (e.g., Andersen et al., 1995; Belkin et al., 1985; Hansteen et al., 1998, 1991; Klügel et al., 2020, 2005; Roedder, 1983) for estimating magma plumbing system structures. However, this study appears to overlook the findings of these prior works. Microthermometric density measurements are more precise than those obtained by Raman spectroscopy when CO2 densities exceed approximately 0.6 g/cm³ (Bakker, 2021; Kobayashi et al., 2012). Additionally, analyzing several tens of fluid inclusions can be completed within a timeframe similar to that of Raman-based density measurements, typically ranging from one day to one week. Therefore, a review of previous studies on fluid inclusion geobarometry using microthermometry and a clear distinction between this method and Raman spectroscopy-based methods should be provided.  
  
L59-62: The manuscript describes Raman-based fluid inclusion geobarometry as if it were a recently developed technique. Consequently, many prior studies that do not fit this narrative are ignored. In reality, Raman-based fluid inclusion geobarometry has been applied to phenocrysts and peridotite for understanding magma plumbing system structures for quite some time (e.g., Bali et al., 2008; Boudoire et al., 2018; Ladenberger et al., 2009; Levresse et al., 2016; Yamamoto et al., 2014, 2007, 2002). The results of prior studies on Raman-based fluid inclusion geobarometry should also be accurately described.  
  
L59-62: This statement is incorrect, as geobarometry using the density of CO2-rich fluid inclusions measured by Raman spectroscopy has been in use for a long time (Bali et al., 2008; Boudoire et al., 2018; Ladenberger et al., 2009; Levresse et al., 2016; Yamamoto et al., 2002). While analytical and data processing methods have indeed become more sophisticated over the last 20 years (Bakker, 2021; Fall et al., 2011; Hagiwara et al., 2021, 2020; Kawakami et al., 2003; Lamadrid et al., 2017; Le et al., 2020, 2019; Remigi et al., 2021; Rosso and Bodnar, 1995; Song et al., 2009; Sublett et al., 2020a, 2020b; Wang et al., 2019, 2011; Yamamoto and Kagi, 2006; Yuan et al., 2017), the time required for analysis has changed very little.  
  
L59-67: The advantages of Raman-based fluid inclusion geobarometry are correctly described, but several drawbacks are not mentioned, which may give readers a misleading impression. Therefore, the following major drawbacks of this method should also be properly described: 1) Geobarometry using the residual pressure of fluid inclusions can only be used in volcanic ejecta where fluid inclusions are present in phenocrysts. Thus, although this method has been used to investigate the structure of magma plumbing systems since at least the 1980s and has been the subject of much research, it has only been applied to specific MORB and OIB volcanoes. 2) The density of CO2 inclusions in olivine is known to significantly decrease due to the plastic deformation of host minerals, fluid diffusion, and fluid-host reaction during transport by magma, compared to that in pyroxene and spinel (e.g., De Vivo et al., 1990; Oglialoro et al., 2017; Scambelluri et al., 2009; Viti and Frezzotti, 2000; Wanamaker and Evans, 1989; Yamamoto et al., 2012). Therefore, the pressure of magma chambers estimated from the density of CO2 fluid may not always reflect the true pressure of the magma chambers for all volcanic eruptions. Even fluid inclusions that have not undergone decrepitation may have unreliable densities. The amount of density reduction due to plastic deformation and fluid diffusion depends on factors such as the host mineral species, the depth of the magma chamber, the ascent rate of the phenocrysts, the temperature of the magma, and the cooling rate at the surface, making simple interpretations impossible. Therefore, it is dangerous to describe fluid inclusion geobarometry as a reliable method without discussing the various uncertainties mentioned above. For example, I cannot agree with using the results of this method to make decisions on whether to evacuate residents. Thus, the authors should describe the applicability and limitations of this method more conservatively.  
  
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Reviewer: 2  
  
Comments to the Author  
See attached.

Review of “Depths in a day – A new era of rapid-response Raman-based barometry using fluid inlusions” by DeVitre et al.

Dear editors and authors

Please accept my apologies for the somewhat delayed review of “Depths in a day”. The review request landed exactly on exam and dissertation marking season, which unfortunately had to take priority. The authors of the manuscript allowed themselves some remarks about the bottlenecks in academic publishing and I am sorry to have caused yet another hold-up in this manuscript’s journey through the review process. I read this manuscript with great interest. A notable feature of melt and fluid inclusion barometry papers over the past few years has been the hopeful promise of developing these approaches for real-time application during volcanic crises, but until now I’m not aware of any study that has actually attempted this. It was refreshing to read a manuscript that has actually been able to demonstrate a proof-of-concept that near-real-time petrological monitoring using fluid inclusions is a viable route towards providing information on magma storage depths to volcano observatories. I agree with the original reviewers that the approach itself is not novel; however, in my opinion there is great scientific value in having a published account of this first demonstration that magma storage pressures can be measured and communicated in near-real time. The readership of JPet will include many scientists using melt and fluid inclusion barometry approaches in their own research, so a JPet letter demonstrating a case study of rapid-response fluid inclusion barometry will reach an interested audience. The letter is well written, clearly explained, and reaches beyond the immediate case study of the September 2023 Kilauea eruption into a well-articulated discussion of the types of volcano and volcanic setting where rapid-response barometry has genuine potential as a near-real-time monitoring tool. I recommend to publish the letter with minor revisions. In my view the authors have done an excellent job responding to the comments of the original reviewers. Specifically, they have explained and quantified the uncertainties in their temperature estimates; they have addressed concerns regarding EOS for pure CO2 fluid vs a mixed H2O-CO2 fluid, and the effect of variable XH2O on the calculated pressures; justified their choice of Raman densimeter; and justified the types of images used in their workflow. I would have appreciated specific direction to the changed text in the revised manuscript where these concerns were addressed. I thought the authors did not quite address the concern of Reviewer 1 “How are the data used by decision makers” – and this is also in my mind whenever rapid-response petrological monitoring is discussed. I agree with lines 81-84 (specific recommendations of CONVERSE) that assessing magma storage depth is a key science question in an unfolding eruption, but it’s less clear how observatories would actually use that information to inform the hazard response and management. Perhaps it is as simple as being able to maintain good relationships with local communities by being able to answer questions on where the magma is coming from; how long it may have been stored for; what is its pre-eruptive temperature and viscosity. But are there other ways in which real-time barometry informs ongoing hazard assessments or changes to the crisis response? The case study presented was a low-hazard event so perhaps there are no examples for this particular event, but the discussion or conclusion could usefully include a couple of sentences explaining specifically how the HVO envisages that near-real-time fluid inclusion barometry would feed into their workflows and decisions in a more hazardous scenario. I’ve attached commented word documents of the manuscript and the supplementary appendix. In the manuscript, please note that “fluid inclusion” and “melt inclusion” almost never need a hyphen – please could this be changed throughout? I picked up a few other typos and grammatical errors. Sorry this is picky, but I think it will aid good communication to sort these out. Almost all the other comments on the mark-up word documents are very minor and should take very little time to fix. Thanks to the authors for an interesting read, and best of luck seeing this manuscript through to publication.

Best regards,

Margaret Hartley

University of Manchester

We thank the reviewer for their thorough work and appreciation of our study. We have addressed the specific comments from the attached pdf documents and screenshot below the majority of unrepeated comments (for example, we do not screenshot all the hyphen corrections, though we have addressed all of them).

We have also addressed the reviewer’s comment about the utility of the method and how HVO envisions the method will fit into their workflows and decisions (see screenshot below).

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We have changed this throughout the text.

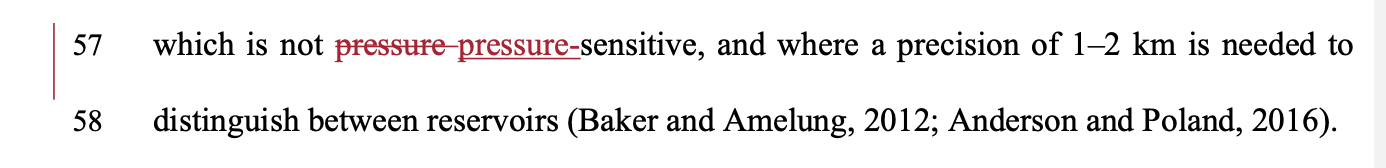


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We changed the sentence to “Recent developments have shown that Raman-based barometry of CO2-rich fluid inclusions provide much smaller uncertainties than mineral barometry, and require far less time and resources than melt inclusion analyses (Dayton et al., 2023; DeVitre and Wieser, 2024).”



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We moved this sentence earlier as suggested by the reviewer. It is now: “ Recent studies have speculated that fluid inclusion barometry could be performed quickly enough to be useful for near-real-time volcano monitoring (Dayton et al., 2023; Zanon et al., 2024). The CONVERSE Hawai‘i Scientific Advisory Committee (Cooper et al., 2023) specifically recommended that key science questions should be identified, and pre-planning science activities performed, to facilitate more rapid implementation across a broader scientific group during hazardous eruptions. Here, we performed a near-real-time simulation to rigorously assess how quickly fluid inclusion depths can be obtained from erupted material, and whether these timescales are short enough to have utility as a petrological monitoring tool.[..]”

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We amended this to observatory or academic staff, given that no special circumstances or outside of hours work was needed to complete the work on the academic research side.

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We agree and hence changed these to match the reviewer’s suggestion.

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We added a reference to DiadFit earlier in the text, right before discussing the H2O presence in the fluid: “All spectra processing and subsequent calculations were performed using DiadFit (Wieser and DeVitre, 2024), allowing for a daily data-to-results turnaround of ~15 minutes. Pressures were calculated using the pure CO2 EOS of Span & Wagner (1996) implemented in DiadFit. At the time of our simulation, it was challenging to perform EOS calculations considering the possible presence of H2O in the exsolved fluid due to a lack of publicly available software running on modern operating systems.”

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Comments were addressed in the text (see tracked document)

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Changes made. Hyphens for fluid-inclusion removed throughout the text.

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Changes made. We replace with percentile.

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Change made as requested by reviewer.

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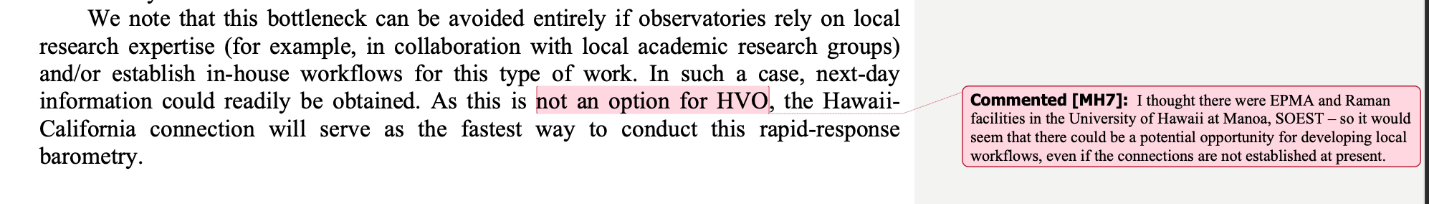
Regarding the first comment, this was unfortunately out of our hands – we had to submit the files as requested by the journal and pdf was not accepted as a figure format at time of submission. In any case, we agree that the journal should consider expanding the formats available at the time of submission.

As for the second comment, we thank the reviewer for pointing this out. It was just a mistake in the x axis scale of pressure for panel a and has now been fixed.

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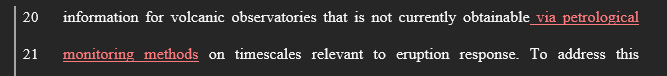
These comments have been addressed in the supplement. There was a mismatch of versions and figures that has been fixed.



We agree that there may be potential to build a local workflow, though using the facilities at Manoa would still require shipping samples in some capacity, thus not significantly different from the current collaboration. Additionally, the Raman facilities at UH Manoa are not currently calibrated for this type of measurement.

Reviewer: 3  
  
Comments to the Author  
Review for “Depths in a Day”

20-21: depth of magma storage … high-priority information for volcanic observatories that is not currently obtainable on timescales relevant to eruption response: I wonder if this is a stretch. There are several cases with geophysical monitoring and seismic data are fully capable of detecting the depth of magma storage and movement prior to eruption onset. Grindavik for example. What I think would be better is instead highlighting the petrological monitoring aspect.

We agree with the reviewer that geophysical methods can probe for this information when the monitoring networks are good enough. Therefore, we emphasize that the information is not obtainable via petrological monitoring methods (screenshot).

90: I would have liked to see this method applied to a volcano with much less precise information than Kilauea. Is it possible to either do this, or add on a section where you go through the hypothetical process of navigating a case study with little to no prior information?

Using Kīlauea as a testing ground was intentional because the information is so well constrained, and the eruption was a very low-risk and low-stakes scenario and therefore the responsible choice for a stress-test such as this. This is based on the suggestions of CONVERSE, and different other studies such as Andrews et al., 2019 and Diettrich and Neal 2022 which we mention near lines 79-80. “The CONVERSE Hawai‘i Scientific Advisory Committee (Cooper *et al.*, 2023) specifically recommended that key science questions should be identified, and pre-planning science activities performed, to facilitate more rapid implementation across a broader scientific group during hazardous eruptions.[..] Performing these simulations during relatively small, low- hazard eruptions (as here) or as hypothetical simulations (e.g., (Andrews et al., 2019)) is vital to iron-out bottlenecks so that we are as prepared as possible for the next large volcanic crisis (Dietterich and Neal, 2022)”. We appreciate that due to the manuscript’s organization, this was not clear in the previous version and in accordance with Reviewer#2’s suggestion, we’ve now moved this statement earlier in the introduction.

However, we have added a small section in the broader applicability on navigating a volcano with little information available.

108: What about samples without CO2 fluids? As in, samples that are pure melt inclusions?

Is the presence of fluids a pre-requisite for this approach?

Fluid inclusion barometry requires the presence of fluids and specifically of CO2 with little other fluids (the effect of H2O, for example, is discussed in the supplement). In the case of melt inclusions, the appropriate approach would be volatile solubility modelling. We are not sure what the reviewer is getting at in this comment. If the samples do not have fluid inclusions, then this method is inherently not appropriate.

241-244: I think this goes against your initial paragraph – indeed, this method is not

applicable to regions with little to no data, its only applicable to highly active regions that

inherently has a lot of available/published data.

It appears that the line numbers reported by the reviewer as different from those in our documents and the annotated pdf provided by the editor. We cannot find the statement that the reviewer is referring to. In any case, we disagree, the method is applicable to regions with little data – a survey can be conducted in such regions, with some educated guesses about for example temperature of entrapment based either on existing glass/mineral data and or regional information. As we demonstrated, the effect of entrapment temperature is minimal on the results. In the case of XH2O, we suggest that a first order estimation can be made based on the compilation presented in this study. For example, if one were to look at a poorly studied alkaline OIB, the trend in pressure vs XH2O for alkaline OIBs could be used to gain a first order approximation of XH2O for the sample suite in question. We mention this in the text. In such cases, the appropriate course of action would be to conduct a survey of fluid inclusions in existing sample suites from previous events.

245: I’m pretty sure the Venugopal paper was not a Cascades paper, it was a Garibaldi Arc

paper – these are two different subduction zones based on the tectonics, chemistry, and

age. I think this needs to be updated in your figures too

We disagree with the reviewer. This paper indeed is a paper about the Garibaldi Volcanic Belt. However, as is shown clearly in Hildreth (2007), the Garibaldi Volcanic Belt is in fact part of the Cascades and results from the subduction of the same tectonic plate. Therefore, we do not consider that this needs to be updated.

250: There is no denying that Raman analyses of vapour bubbles is essential to crack the

code on CO2 – but if this is a pre-requisite for samples that qualify for your “Depth in a day”

aim, then I think there is a big discrepancy here. If pre-determined Raman data is needed,

how would you provide magma storage depths? Please correct me if I’m wrong but it seems

like there is an inherent positive bias here –systems with lots of data are further spotlighted,

and systems with little to no data are made even more inaccessible. This further highlights

my point above.

We do not mean that it is a pre-requisite, but rather that XH2O estimated worldwide from our compilation is probably an overestimate. What this means is that our XH2O compilation shows “a worst-case scenario”, such that IF all of the melt inclusion data in the compilation had originally considered CO2 in the bubbles, the XH2O estimated would likely be much smaller than they are currently portrayed. In essence this means that perhaps the technique is more broadly applicable than this shows. In any case, it also means that the correction on pressure is likely smaller than what could be estimated using glass-only melt inclusion data. It does not mean that systems with little data are made more inaccessible, it only means that the uncertainty is a bit smaller on systems with more data – but not prohibitively. One can still use a basic estimate of XH2O from the compilation based on the composition of the samples, or from existing MI data (if it exists) along with an estimate of entrapment temperature based on composition and calculate a pressure from fluid inclusion data.

256: I appreciate this point as it addresses my concerns! But what are the range of errors

when needing to estimate XH2O? Is it within the capabilities of the depths in a day

approach?

259: I think this line is a little too vague and almost feels like an afterthought. I think this

needs to be a section on its own. How would datasets with and without prior Raman data

subjected to your Depths in a day method compare to solely using mineral-melt

thermobarometry?

Overall, I find this to be a great study with broad applicability. My main concerns stem from

the sensationalizing of the lack of magma storage depth information from monitoring

techniques and the applicability to volcanic systems with little to no prior data (when really

its not entirely possible and/or incurs additional error). I also have concerns over sample

type – what about systems that predominately erupt via lava flows? Would that qualify for

this approach? Systems like Stromboli – where its very hard/dangerous to access freshly

erupted tephra – how would that work? I appreciate the concept, but I feel like the

execution is a lot more complicated than this paper makes it seem. Can an EOS be

generated for fluids hosted in minerals other than olivine? Or is it specific to olivine hosts?

I feel like in its present state – it is two separate papers that could be expanded upon. Your

workflow to calculate depths in a day and the theory behind it is excellent. But I feel like

that should be a paper on its own, with the addition of several sections: application to

systems without prior raman data, applications to systems that emit lava flows, applications

to systems to very little knowledge. Once you’ve established this, then I feel you could go

into detail about global applicability as you have done. I fear that this journal format is not

for this paper – either make it longer as a true JPet paper, or publish companion papers and

the broad applicability section could qualify for a short JPet paper