**Supporting Information for**

‘Depths in a day - A new era of rapid-response Raman-based barometry using fluid inclusions’

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**Additional Supporting Information (Files uploaded separately)**

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All other raw data (spectra, metadata, FI images) as well as raw Jupyter processing notebooks can be found on a Github repository (<https://github.com/cljdevitre/2023_Kilauea-rapid-response-simulation>) which will be archived at Zenodo upon acceptance.

**Text S1. Sample collection and preparation**

Tephra samples (USGS code KS33-588) representing the first ~14 hours of the September 10, 2023, eruption of Kīlauea volcano were collected by Hawaiian Volcano Observatory (HVO) geologists on September 12 and shipped on Friday September 15 at ~5 pm HST (Fig. S1). This tephra was erupted from a fissure which opened at 15:36 local time on September 10 (~22 minutes after the eruption started, between 15:13 and 15:14 local time) and ceased erupting between 06:16 and 06:18 am local time on September 11. Following receipt of the samples at the University of California (UC), Berkeley on Tuesday September 19, material was processed in a jaw crusher in the VIBE lab which was thoroughly cleaned the week before and the morning of the simulation, and then sieved into >2 mm, 1–2 mm, and 0.5–1 mm size fraction. Crystals were picked from the 1–2 mm and 0.5–1 mm size fraction using three different binocular microscopes (one of which had the ability to cross polars). Then, crystals were individually mounted in CrystalBond™ on glass slides and progressively polished with 1200-2500-10000 grade wet and dry paper to find fluid inclusions (FI). Grains containing FI were then passed onto a team member on a research-grade microscope to take reflected and transmitted light images to aid with Raman navigation. These images were pasted into a Google slides document so all lab personnel at UC could access them immediately (images are compiled in supplement S5 FI Image Compilation as an example).

A lava flow sample (USGS code KS33-587) was collected in a molten state and quenched with water at 6:30 AM HST on the 11 of September 2023. The sample was entirely glassy, and fragments were mounted in a 1” epoxy round and polished for microprobe analysis.

A diagram of a machine

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***Figure S1. Workflow of the study, all times on this figure are Pacific Standard Time (PST).*** *Stick people show the contribution of individual team members, to indicate the total time associated with each step. We note that AB was trained in these procedures during the simulation and all reports were sent to HVO prior to 5:30 pm Hawaii Standard Time (HST), thus allowing for decision making for the following day.*

Text S2. Raman analyses

Raman spectra were acquired using a WiTec Alpha 300R Raman spectrometer at the Department of Earth and Planetary Science at the University of California, Berkeley. The relationship between CO2 density and spectral features was determined from a gas calibration cell following the methods of DeVitre and Wieser (2024). All spectra were acquired from samples heated to 37 ℃. Spectra were processed and corrected for drift using the Python tool DiadFit v0.0.73 (Wieser and DeVitre, 2024). We report ratios of SO2 to CO2 peak areas. We filtered the final dataset for SO2/CO2 ratio < 0.22 (Fig. 1d), to ensure use of the pure CO2 EOS was valid (given an instrumental efficiency of 1 for our Raman, this corresponds to <10 mol% SO2). No fluid inclusions contained carbonate peaks nor any gaseous species other than CO2. We calculated densities from the Raman-measured separation of the Fermi diad using the appropriate calibrated density equations for our instrument in DiadFit v.0.073 (Wieser and DeVitre, 2024). For the final dataset (Day 4), we took a mean of duplicate analyses, and calculated pressures using the EOS of Span and Wagner (1996) using an entrapment temperature estimated from the Fo content close to the FI (DeVitre and Wieser, 2024). Entrapment depths in Fig. 1 were calculated using a constant crustal density of 2300 kg/m3 and a normally distributed 1**σ** error of 100 kg/m3. Error in the CO2 density for each FI was determined from the error in each peak fit, the Ne line drift correction model, and the densimeter (Wieser and DeVitre, 2024). We used a 40℃ error for temperature (DeVitre and Wieser, 2024). We propagated these three sources of uncertainty in FI depths using MonteCarlo simulations implemented in DiadFit v0.0.73. We later recalculated pressures using the EOS of Duan and Zhang (2006) implemented in a newer version of DiadFit (v.0.0.85) to assess the effect of XH2O on our results (Fig. 1d “H2O effect” histogram). Further details can be found in section S8 of this supplement (“Text S8. Effect of H2O on calculated pressures”). In total we analyzed 62 FI hosted in 31 olivine crystals. Our workflow is detailed in Fig. S1. Pictures of each FI and host crystal are available in the repository linked at the beginning. We note here that the initial data reported for days 1 and 2 did not account for repeated analyses (1 repeated FI in Day 1 and 6 in Day 2; we took a mean of repetitions on Day 4), pressures were calculated using an estimated entrapment temperature of 1150˚C (Wieser *et al.*, 2021; DeVitre and Wieser, 2024), and depth was calculated using the crustal density model in Ryan (1987) and Lerner *et al.* (2021).

**Text S3. Epoxy mount making and polishing**

After Raman analysis, crystals were removed from CrystalBondTM\* using a hotplate and placed in acetone. They were then mounted on double-sided sticky tape with their polished side down. EpoFixTM\* resin was used to impregnate the samples in a Cast-N-Vac vacuum pourer. After curing, the epoxy mount was polished using an EcoMet30 automatic polisher, with 9, 3, and 1 µm diamond pastes. A reflected light map and image of each crystal was taken using the Raman microscope to aid SEM sample navigation. The location within each FI in the reflected light image was cataloged so the scanning electron microscope (SEM) operator knew where to analyze to obtain an approximate Fo content for each FI.

**Text S4. EDS analysis**

Samples were carbon coated to an approximate thickness of 25–30 µm for EDS analysis. Chemical data for each host crystal in the proximity of each FI was determined using a Zeiss EVO MA-10 SEM and a single AMETEK EDAX 10 mm2 detector at the University of California, Berkeley. The beam was rastered over a 30-by-30 µm area for ~75–80s (a live time of 60 seconds with ~30% dead time). For all analyses we used an accelerating voltage of 20 kV and a 30 µm aperture, giving an approximate beam current of 5 nA. EDS data reduction was performed using an in-built standardless quantification routine (including a ZAF matrix correction), alongside pre-determined “Standardless Element Coefficients” (SECs). The SECs act as correction factors for each element in the standardless quantification routine and have been determined through several years of repeat analyses of multiple different silicate standard materials and glasses. This method returns an estimate for the relative abundance of each element in the analyzed material and, if a normalization to 100% is assumed, can be used to return semi-quantitative chemical analysis of elemental or oxide weight percent values. However, for the purposes of this study we simply focused on the relative abundance of Mg and Fe in the EDS analyses to calculate the Fo content of the olivine host crystals. Furthermore, by calculating the molar Si/(Mg+Fe) ratio of each analysis we were able to provide a stoichiometric check of data quality: we obtained an average Si/(Mg+Fe) ratio of 0.497±0.006 on Kīlauea olivine crystals, close to the ideal value of ~0.5. Precision and accuracy were determined through repeat measurements of the San Carlos and Springwater olivines, which were not used as part of the standard quantification routine. We estimate the precision and accuracy of the method using repeat analyses of secondary standards (5 at start, 5 at end of day), which have Fo contents similar to our samples (see supplementary dataset S3). The Smithsonian-preferred Fo content (Jarosewich *et al.*, 1980) for the San Carlos secondary standard is 90.2 mol% Fo, and we obtained a mean of 89.84±0.07 mol% Fo. For Springwater, the preferred value is 82.4 mol% Fo, and we obtained a mean of 82.1±0.2 mol% Fo. We also analyzed a Kīlauea olivine crystal previously measured on the USGS Menlo Park EPMA. The average Fo content obtained at Menlo Park was 87.8±0.1 mol% Fo, and at the University of California, Berkeley SEM, 88.5±0.1. It should be noted that such offsets also exist between different EPMA labs (Wieser *et al.*, 2023b). Considering these probable differences, we compared data acquired at Stanford University to that obtained at Cambridge University on the olivine crystals of Wieser *et al.* (2021). The difference observed amounts to ~0.62 mol% at Fo~82 and 0.78 mol% at Fo90 (DeVitre and Wieser, 2024). Thus, EDS errors are within uncertainty of offsets between different microprobe labs.

Text S5. EPMA analysis of glasses

Major and minor element analysis of glass from USGS sample KS33-587 was done using the U.S. Geological Survey’s JEOL 8530F microprobe at the California Volcano Observatory (CalVO). The samples were run over midnight between September 23 and 24, 2023, in 1hr 37 minutes (9/23/2023 23:06 - 9/24/2023 0:43). A total of 20 total analyses were conducted, corresponding to 4 analyses per grain in 5 grains. These samples were run as part of a pre-booked session for other samples that started on September 20th. We note that CalVO microprobe personnel later informed us that it would be possible in the future to request immediate access for eruption response if needed. This would mean that a glass mount could be prepared in 24 hrs after sample collection, shipped within 2 days from HVO to CalVO and analyzed on the probe on day 4 post field collection (calibration takes 2-3 hrs and analysis ~2 hours). We also note that if these measurements did not exist at the time of the simulation, we could have used the EDS-SEM method to get the Mg# of the host glass to calculate the equilibrium olivine Fo content shown on Fig. 1 (the only reason we needed these EPMA data). EDS measurements on the matrix glass were within 1-2 Mg# units of EPMA measurements – far smaller than the uncertainty associated with calculating an equilibrium olivine content based on uncertainty regarding the choice of olivine-liquid KD model at Kīlauea.

Microprobe glass analyses used 15 kV accelerating voltage and a 10 µm beam with a 10 nA current. Peak counting times were 45 s for S, Cl, and F, 40 s for Ti, P, and Mn, 20 s for Si, Ca, Fe, Al, and Mg, and 10 s Na and K (backgrounds were measured on both sides of the peak for half the peak counting times). Standards were VG-2 basaltic glass (USNM 111240/52; Jarosewich *et al.*, 1980) for Si, Mg, and Al, Kakanui pyrope garnet (USNM 143968) for Fe, and Al, wollastonite for Ca, Tiburon albite for Na, MnO3 for Mn, TiO2 for Ti, orthoclase OR-1A for K, Wilburforce apatite (USGS-M105731) for P, barite for S, sodalite for Cl, and MgF2 for F. Two-sigma relative precision, based on two analyses of VG-2 glass (before and after the lava sample was analysed), are 0.19 wt% for SiO2, 0.15 wt% for Al2O3, 0.003 wt% for TiO2, 0.27 wt% for FeO, 0.009 wt% for MnO, 0.006 wt% for MgO, 0.04 wt% for CaO, 0.11 wt% for Na2O, 0.02 for K2O, 0.04 for P2O5, 0.07 for SO3, 0.0001 for Cl, and 0.002 for F. X-ray intensities were converted to concentrations using standard ZAF corrections (Armstrong, 1988). Analyses with totals <99.0 wt% or >100.5 wt% were rejected. Reported analyses are an average of four replicate points on individual glass fragments.

Text S6. Manuscript Writing Timeline

The study presented here was formulated into a letter over days 4 and 5 (September 23-24th), sent to our co-authors on Day 6 (September 25th) and submitted for review to Nature Geoscience on Day 8 - September 27th, 2023 (see S6\_Email\_and\_tracking\_record for email confirmations), one week after we begun the simulation. Unfortunately, despite our prompt submission, we did not receive a rejection notification until a month later, owing to editorial delays. The rejection, based on the grounds of 'lack of appeal for the broader geoscience community', was surprising, given the significant interest of the geoscience community in hazard mitigation. We proceeded to submit the manuscript to PNAS on October 31st, 2023 (see S6\_Email\_and\_tracking\_record) who rejected the manuscript on November 15th (see S6) on similar grounds with the editor comments as follows: “This is indeed an interesting real-time procedure but may be too specialized for PNAS”. After submitting to Journal of Petrology on November 16th, 2023, we received a rejection from JPET on January 19th, 2024, based on concerns from reviewers of temperature sensitivity of EOS and the lack of applicability to subduction zones (S6). We have addressed these concerns with the new Fig. S1 and Fig. 3 and further details in the supplement and body of the article and believe the new manuscript has significant global applicability. The revised manuscript was then submitted to Science Advances on March 16th and subsequently rejected on April 12th as it was deemed better suited for a specialized journal. Following this, we resubmitted to JPET on April 24th and received a major revisions decision on July 16th. Regardless, it is evident that the delays in the editorial and publishing process constitute possibly the biggest bottleneck for reporting findings to the community, particularly given USGS collaborations mean that results cannot be posted as preprints prior to peer review.

Text S7. Identifying and Resolving Bottlenecks

The yellow stars on Fig. S1 identify current bottlenecks in the process that could be easily improved.

***Star 1 – Shipping and receiving samples***

Distributing samples to the University of California, Berkeley was not a top priority for HVO because this simulation was being attempted for the first time, and as such, there was no guarantee of obtaining magma storage depths in a timely manner. Samples were shipped from Hilo on a Friday at ~5 pm HST. HVO was asked to ship samples to a private residence under the assumption that they might arrive over the weekend. However, no packages leave Hilo after 4pm on Friday over the weekend, so the samples started their transit to California on Monday. Had the package been taken to the courier’s office on Friday morning, it would likely have arrived on Sunday. The tracking information indicated arrival on Wednesday, which is when we planned to start the simulation. However, the samples arrived at the private residence on Tuesday morning during working hours, without notification that the package had been delivered (and no one was home).

We have demonstrated that this technique adds valuable quantitative depth information that expands on HVO’s routine near-real-time chemical monitoring with bulk rock ED-XRF (Gansecki *et al.*, 2019). Under ideal circumstances, HVO geologists would sample tephra or molten lava from the eruption on Day 1 (morning) and dry the samples in the lab on Day 1 (afternoon), dropping the samples for shipment on the evening of Day 1, which would go out early on Day 2 (as long as the drop-off did not occur Friday afternoon or over the weekend). Same-day shipping from Hawaii to California is not realistic, but samples shipping Monday through Thursday mornings would allow for arrival on Day 3. Additionally, it would be possible to get samples to the University of California, Berkeley within 24 hours if someone in Hawai’i were to take a flight to San Francisco or Oakland airport with the samples, or within ~30 hours if someone based in the University of California, Berkeley flew to Hawai’i, picked up the samples, and returned home immediately.

We note that this bottleneck can be avoided entirely if observatories rely on local research expertise (for example, in collaboration with local academic research groups) and/or establish in-house workflows for this type of work. In such a case, next-day information could readily be obtained. As this is not an option for HVO, the Hawaii-California connection will serve as the fastest way to conduct this rapid-response barometry.

***Star 2 – Sample cataloging***

The WiTec Raman microscope used in this study does not have a condenser in its optical path, which can make it difficult to navigate and find FIs directly, particularly in volcanic crystals that are commonly coated in glass. The first 7–10 crystals were analyzed immediately after preparation with no navigation photos, so finding the FI on the Raman scope added some time. After AB had finished crushing, sieving, and picking, he began taking photos on a research-grade microscope to help the Raman operator find the FIs they were supposed to be analyzing. Late on Day 2, when students were not available, Wieser began photographing crystals holding her phone to the eyepiece of the teaching-collection reflected light and transmitted light microscopes. This provided enough textural context to easily find FIs on the Raman (See Image Compilation S5 in the repository). The main advantage of using smartphones is that the person who found each FI could identify it, rather than passing it off to another person who then must work out where the FI is before photographing it. This would greatly reduce the number of people needed for the simulation, as we almost always had one person taking photos.

***Star 3 – Epoxy impregnation***

We used EpoFixTM epoxy in our laboratory because it gives low backgrounds during SIMS analysis. After pouring the epoxy at ~7 pm, it was removed from its mount at ~9 am the next morning. The epoxy was still noticeably soft (to the extent it cracked coming out of the mould). This meant that we could not start polishing immediately. Instead, we had to wait a further ~5 hours for it to cure sufficiently to polish. If fast-curing epoxies were available, it is very possible that a team member could have stayed and polished and cataloged the sample overnight, allowing SEM analysis on Friday (Day 3) rather than Saturday.

Text S8. Effect of H2O on calculated pressures

The exsolved fluid phase in shallow magmatic systems like Kīlauea is not pure CO2, but rather contains a proportion of H2O. Fluid inclusion studies typically assume that H2O has been lost and therefore the measured CO2 density must be corrected based on the molar fraction of H2O and molar ratios (see Hansteen and Klügel, 2008). With this, pressures can be calculated using a mixed H2O–CO2 equation of state. Although it was not possible to implement these calculations during our simulation, a recent paper (Yoshimura, 2023) made it possible to implement these corrections starting in DiadFit v0.0.85. We recalculated pressures for our fluid inclusions using mol fractions of H2O in the exsolved fluid calculated based on the polynomial equations for Kīlauea in DeVitre and Wieser, (2024). We iterated measurements 5 times and show calculated on Fig S2; the data for iteration 5 is reported are the full FI dataset (Dataset S3) and the Jupyter notebook is available in the repository. We plot the recalculated histogram of depths on Fig.1d. We note that for all 3 days, the mean and median correction factor is ~10%. Most FI have correction factors <20%. These correction factors do not shift our FI from one reservoir to another, therefore they do not affect the interpretation of our results.

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**Fig. S2**. Cumulative probability plot of the ratio of pressures from the mixed fluid EOS and pure CO2 EOS depending on the  function applied from (DeVitre and Wieser, 2024) for each day of the simulation.

Text. S8. Sensitivity of the EOS method for FI to entrapment temperature – Extended

We test the sensitivity of 3 equations of state for CO2 available in DiadFit: two are for pure CO2 (Sterner and Pitzer, 1994; Span and Wagner, 1996) and one for CO2-H2O mixtures (Duan and Zhang, 2006). For this, we calculated pressures using all three EOS at different magmatically relevant entrapment temperatures (for the mixed H2O-CO2 EOS we used  = 0.1) which encompass the entire range of measured olivine-saturated liquid temperatures at Kīlauea volcano (1100,1150, 1240 and 1350 ˚C). Overall, none of the three equations of state are significantly sensitive to temperature at these magmatic temperatures (Fig. S3-S6). The shaded box in Fig. S3 shows storage conditions relevant to Kīlauea. In the worst case, at the depth of the HMM reservoir (1 km), the absolute uncertainty in depth due to temperature is ~0.15 km and at depths corresponding to the SC reservoir (~4 km) it is ~0.7 km. We plot in detail on Figs S4-S6 the temperature sensitivity for each of the EOS at general conditions and conditions specifically relevant to Kīlauea volcano.

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Fig. S3. % Percentage difference in pressure (a) and absolute difference in depths (b) for pressures calculated at 1350˚C and 1150˚C using two pure CO2 EOS (SW96, Span and Wagner, 1996; SP94, Sterner and Pitzer, 1994) and one mixed H2O-CO2 EOS (DZ06, Duan and Zhang, 2006). Shaded area indicate pressures and depth relevant to Kīlauea pre-eruptive magma storage.

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Fig. S4. Temperature sensitivity of the mixed CO2-H2O equation of state at 0.1 mol% H2O (Duan and Zhang, 2006).(a) Pressure vs CO2 density calculated for various entrapment temperatures relevant at Kīlauea volcano. 1150 ˚C was our initial fixed temperature for days 1 and 2; 1240 ˚C is the rounded mean and median of all measured temperatures in our final dataset. (b) Depth and pressure differences induced by uncertainty in temperature. Blue curves show the % difference in pressure (or depth) and maroon curves show the absolute difference in depth in km. (c) Close-up of panel a, representing relevant PT conditions for Kīlauea volcano. Grey boxes show the depth range of the magma storage reservoirs – HMM for Halema’uma’u and SC for South Caldera – inferred from FI and MI barometry as well as geophysics (DeVitre and Wieser, 2024; Lerner *et al.*, 2024). Stars show hypothetical FI trapped at HMM and SC reservoirs with error bars representing 1σ uncertainty from Monte Carlo simulations using a temperature uncertainty of ±150 K. (d) Close-up of panel b, showing depth and pressure differences induced by uncertainty in temperature for PT conditions relevant to Kīlauea volcano. Blue curves show the % difference in pressure (or depth) and maroon curves show the absolute difference in depth in km.

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Fig. S5. Temperature sensitivity of Span and Wagner (1996) pure CO2 equation of state.

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Fig S6. Temperature sensitivity of Sterner and Pitzer (1994) pure CO2 equation of state.

Text S10. Global Melt inclusion compilation

We compiled melt inclusion datasets with published major element data, H2O and CO2 concentrations in the glass from EarthChem (https://www.earthchem.org/), Georoc (https://georoc.eu/), Rasmussen *et al.* (2022), DeVitre *et al.* (2023) and Wieser *et al.* (2023c) as well as other MI datasets from the literature (Harris and Anderson Jr, 1983; Anderson and Brown, 1993; Roggensack *et al.*, 1997; Roggensack, 2001a, 2001b; Saal *et al.*, 2002; Cervantes and Wallace, 2003; Wade *et al.*, 2006; Benjamin *et al.*, 2007; Sadofsky *et al.*, 2008; Vigouroux *et al.*, 2008; Auer *et al.*, 2009; Famin *et al.*, 2009; Johnson *et al.*, 2009; Kelley and Cottrell, 2009; Koleszar *et al.*, 2009; Roberge *et al.*, 2009; Zimmer, 2009; Cooper *et al.*, 2010, 2022; Kelley *et al.*, 2010; Ruscitto *et al.*, 2010, 2011; Shaw *et al.*, 2010; Zimmer *et al.*, 2010; Esposito *et al.*, 2011; Head *et al.*, 2011; Helo *et al.*, 2011; Mormone *et al.*, 2011; Schipper *et al.*, 2011; Berlo *et al.*, 2012; Bouvet de Maisonneuve *et al.*, 2012; Field *et al.*, 2012; Rose-Koga *et al.*, 2012; Wanless and Shaw, 2012; Wysoczanski *et al.*, 2012; de Moor *et al.*, 2013; Lloyd *et al.*, 2013; Brounce *et al.*, 2014; Hartley *et al.*, 2014; Métrich *et al.*, 2014; Myers *et al.*, 2014; Sides *et al.*, 2014; Wanless *et al.*, 2014, 2015; Cassidy *et al.*, 2015; Colman *et al.*, 2015; Hudgins *et al.*, 2015; Moore *et al.*, 2015, 2018, 2021; Plechov *et al.*, 2015; Ribeiro *et al.*, 2015; Wallace *et al.*, 2015; Aster *et al.*, 2016; Druitt *et al.*, 2016; Ruth *et al.*, 2016; Venugopal *et al.*, 2016, 2020a, 2020b; Walowski *et al.*, 2016, 2019; Donovan *et al.*, 2017; Hauri *et al.*, 2017, 2021; Longpré *et al.*, 2017; Rasmussen *et al.*, 2017; Robidoux *et al.*, 2017, 2018; Allison, 2018; Bali *et al.*, 2018; Bennett *et al.*, 2019; Gennaro *et al.*, 2019; Manzini *et al.*, 2019; Miller *et al.*, 2019; Taracsák *et al.*, 2019; Iddon and Edmonds, 2020; Allison *et al.*, 2021; Hernandez Nava *et al.*, 2021; Lerner *et al.*, 2021; Rasmussen and Plank, 2021; Wieser *et al.*, 2021; Gleeson *et al.*, 2022; DeVitre *et al.*, 2023; Wong *et al.*, 2023).

We calculated saturation pressures and the fraction of H2O in the exsolved fluid phase () using the MagmaSat solubility model (Ghiorso and Gualda, 2015) implemented in VESIcal (Iacovino *et al.*, 2021). Whenever measurements were available, we used total CO2 contents calculated from mass balance for Raman-measured MI bubbles, otherwise we use glass-only CO2. When possible, we use post-entrapment crystallization corrected MI concentrations. As a first approximation, temperatures were calculated from major element data using the CaO liquid-only thermometer of Helz and Thornber (1987) implemented in Thermobar (Wieser *et al.*, 2022) as it is not pressure sensitive. From there we calculated saturation pressures using MagmaSat in VESIcal (Iacovino *et al.*, 2021). We then used these approximated pressures to recalculate temperatures with the more appropriate ol-liq equation 22 of Putirka (2008) implemented in Thermobar (Wieser *et al.*, 2022)). As we did not have access to olivine-host chemistry, we used the Thermobar function “T\_Put2008\_eq22\_BeattDMg” which couples a theoretical calculation of the DMg from Beattie (1993), to calculate equilibrium olivine compositions so that equation 22 of Putirka (2008) can be used as a liquid-only thermometer. Equation 22 of Putirka (2008) has recently been identified as the most robust liquid-only thermometer across a wide range of compositions (Wieser *et al.*, 2023a). Lastly, we recalculated saturation pressures using MagmaSat and our refined temperatures. We did not recalculate saturation pressures, temperatures or  for MI in the Cascades compilation of (Wieser *et al.*, 2023c) or for (Dayton *et al.*, 2024) except for Ruscitto *et al.*, (2010). It is a known issue that MagmaSat may fail to converge and/or crash during saturation pressure calculations, which can be problematic when calculating saturation pressures on large datasets such as our >4000 MI compilation. To circumvent crashing issues, we implemented a Python multiprocessing routine along with a try-except block using the Python package “multiprocessing”. The dataset is divided into chunks corresponding to 5 times the number of cores available (e.g., for a laptop with 8 logical core processors, the dataset is divided into chunks of 40 samples) to limit the overhead on the processors which can cause memory saturation and crashing. Each chunk is assigned to a processor and run simultaneously. In the case of this study a Dell Inspiron 15 with i7 8 core processor 16 GB memory was used, which limited to a maximum of 8 chunks run simultaneously..Within each chunk, the MI were run one by one within a try-except block such that whenever an error occurred, NaN values were returned along with the error message from VESIcal (Iacovino *et al.*, 2021). Any MI for which MagmaSat did not converge were filtered out in the final dataset. The notebook is included in the data repository. We provide both the complete unfiltered compilation, and the compilation filtered for MagmaSat errors, SiO2 < 57 wt% and MgO < 16 wt%. As discussed in previous sections, our method is not applicable to systems and magmas where is very high, like for example in high-silica magmas where H2O is concentrated due to fractional crystallization and CO2 is lost due to extensive degassing. Therefore, to identify locations in the world where the rapid-response fluid inclusion barometry technique could be relevant, we plot only mafic MI with SiO2 <57 wt% (Fig. S7). Such magmas are likely representative of recharge magmas regardless of tectonic setting. Interestingly, it is evident that  tends to be higher at alkaline intraplate volcanoes than their tholeiitic counterparts at similar pressures (Fig. 3 main text).

We then plot against pressure at each unique location, grouped by tectonic settings (Fig. S8a-e). It is notable that there is a marked increase in at very low pressures (<50 MPa). We filter the dataset presented on Fig 4, and Fig S10 considering a pressure cutoff of 20 MPa, where is very high regardless of setting.

A collage of different types of soil

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Figure S7. Total Alkalis vs Silica diagram for all the MI <57 wt% SiO2 and MgO <16 wt% in our compilation. Larger black edged symbols indicate the medians of specific locations. (a) Intraplate (oceanic and continental) volcanoes in the compilation. We separate OIB-tholeiitic and OIB-alkaline locations based on the medians on this plot. (b) Subduction zone volcanoes. (c) Mid-ocean ridges (d) Continental rifts.

A group of graphs showing different types of pressure

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Figure S8a. Pressure vs at tholeiitic OIB locations.

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Figure S8b. Pressure vs at alkaline OIB locations and Sunset Crater (an alkaline continental intraplate volcano).

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Figure S8c. Pressure vs at continental rift locations.

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Figure S8d. Pressure vs at mid-ocean ridge locations (Part 1). JdFR – Juan de Fuca Ridge, GSC – Galápagos Spreading Center, EPR – East Pacific Rise.

A graph of different types of sea water

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Figure S8e. Pressure vs at mid-ocean ridge locations (Part 2). NAR – North Atlantic Ridge, MAR – Mid-Atlantic Ridge, GR – Gakkel Ridge.

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Figure S8f. Pressure vs at subduction zones (Part 1).

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Figure S8g. Pressure vs at subduction zones (Part 2).

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Figure S8h. Pressure vs at subduction zones (Part 3).

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Figure S8i. Pressure vs at subduction zones (Part 4).

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Figure S10. Boxplots and violin plots of H2O and CO2 contents of melt inclusions in the compilation. Filtered to SiO2 < 57 wt%, MgO < 16 wt% and saturation pressure > 20MPa.

Data S2. (separate file)

Fluid inclusion dataset for this study.

Data S3. (separate file)

Global melt inclusion compilation (described in previous sections).

**Image Compilation S4 (separate file)**

Compilation of images used for navigation during the simulation. These are presented as they were used during the simulation as an example of what is necessary for the technique.

**Email and tracking record S5 (separate file)**

Compilation of tracking labels, email exchange with HVO personnel and editorial process.

**Supplementary references**

Allison, C. M. (2018). *Highly explosive mafic volcanism: the role of volatiles*. Arizona State University.

Allison, C. M., Roggensack, K. & Clarke, A. B. (2021). Highly explosive basaltic eruptions driven by CO2 exsolution. *Nature Communications* **12**, 217.

Anderson, A. T. & Brown, G. G. (1993). CO2 contents and formation pressures of some Kilauean melt inclusions. *American Mineralogist*. GeoScienceWorld **78**, 794–803.

Armstrong, J. T. (1988). Accurate quantitative analysis of oxygen and nitrogen with a W/Si multilayer crystal. *Microbeam analysis*. San Francisco Press, Inc 301–304.

Aster, E. M., Wallace, P. J., Moore, L. R., Watkins, J., Gazel, E. & Bodnar, R. J. (2016). Reconstructing CO2 concentrations in basaltic melt inclusions using Raman analysis of vapor bubbles. *Journal of Volcanology and Geothermal Research* **323**, 148–162.

Auer, S., Bindeman, I., Wallace, P., Ponomareva, V. & Portnyagin, M. (2009). The origin of hydrous, high-δ18O voluminous volcanism: diverse oxygen isotope values and high magmatic water contents within the volcanic record of Klyuchevskoy volcano, Kamchatka, Russia. *Contributions to Mineralogy and Petrology* **157**, 209–230.

Bali, E., Hartley, M. E., Halldórsson, S. A., Gudfinnsson, G. H. & Jakobsson, S. (2018). Melt inclusion constraints on volatile systematics and degassing history of the 2014–2015 Holuhraun eruption, Iceland. *Contributions to Mineralogy and Petrology* **173**, 9.

Beattie, P. (1993). Olivine-melt and orthopyroxene-melt equilibria. *Contributions to Mineralogy and Petrology* **115**, 103–111.

Benjamin, E. R., Plank, T., Wade, J. A., Kelley, K. A., Hauri, E. H. & Alvarado, G. E. (2007). High water contents in basaltic magmas from Irazú Volcano, Costa Rica. *Journal of Volcanology and Geothermal Research* **168**, 68–92.

Bennett, E. N., Jenner, F. E., Millet, M.-A., Cashman, K. V. & Lissenberg, C. J. (2019). Deep roots for mid-ocean-ridge volcanoes revealed by plagioclase-hosted melt inclusions. *Nature*. Nature Publishing Group **572**, 235–239.

Berlo, K., Stix, J., Roggensack, K. & Ghaleb, B. (2012). A tale of two magmas, Fuego, Guatemala. *Bulletin of Volcanology* **74**, 377–390.

Bouvet de Maisonneuve, C., Dungan, M. A., Bachmann, O. & Burgisser, A. (2012). Insights into shallow magma storage and crystallization at Volcán Llaima (Andean Southern Volcanic Zone, Chile). *Journal of Volcanology and Geothermal Research* **211–212**, 76–91.

Brounce, M. N., Kelley, K. A. & Cottrell, E. (2014). Variations in Fe3+/∑Fe of Mariana Arc Basalts and Mantle Wedge fO2. *Journal of Petrology* **55**, 2513–2536.

Cassidy, M., Edmonds, M., Watt, S. F. L., Palmer, M. R. & Gernon, T. M. (2015). Origin of Basalts by Hybridization in Andesite-dominated Arcs. *Journal of Petrology* **56**, 325–346.

Cervantes, P. & Wallace, P. (2003). Magma degassing and basaltic eruption styles: a case study of ∼2000 year BP Xitle volcano in central Mexico. *Journal of Volcanology and Geothermal Research* **120**, 249–270.

Colman, A., Sinton, J. M. & Wanless, V. D. (2015). Constraints from melt inclusions on depths of magma residence at intermediate magma supply along the Galápagos Spreading Center. *Earth and Planetary Science Letters* **412**, 122–131.

Cooper, L. B., Plank, T., Arculus, R. J., Hauri, E. H., Hall, P. S. & Parman, S. W. (2010). High-Ca boninites from the active Tonga Arc. *Journal of Geophysical Research: Solid Earth* **115**.

Cooper, L., Plank, T., Arculus, R., Hauri, E. & Kelley, K. A. (2022). Arc–Backarc Exchange Along the Tonga–Lau System: Constraints From Volatile Elements. *Journal of Petrology* **63**, egac072.

Dayton, K., Gazel, E., Wieser, P. E., Troll, V. R., Carracedo, J. C., Aulinas, M. & Perez-Torrado, F. J. (2024). Magmatic Storage and Volatile Fluxes of the 2021 La Palma Eruption. *Geochemistry, Geophysics, Geosystems* **25**, e2024GC011491.

de Moor, J. M., Fischer, T. P., King, P. L., Botcharnikov, R. E., Hervig, R. L., Hilton, D. R., Barry, P. H., Mangasini, F. & Ramirez, C. (2013). Volatile-rich silicate melts from Oldoinyo Lengai volcano (Tanzania): Implications for carbonatite genesis and eruptive behavior. *Earth and Planetary Science Letters* **361**, 379–390.

DeVitre, C. L. *et al.* (2023). Oceanic intraplate explosive eruptions fed directly from the mantle. *Proceedings of the National Academy of Sciences*. Proceedings of the National Academy of Sciences **120**, e2302093120.

DeVitre, C. L. & Wieser, P. E. (2024). Reliability of Raman analyses of CO2-rich fluid inclusions as a geobarometer at Kīlauea. *Geochemical Perspectives Letters* **29**, 1–8.

Donovan, A., Blundy, J., Oppenheimer, C. & Buisman, I. (2017). The 2011 eruption of Nabro volcano, Eritrea: perspectives on magmatic processes from melt inclusions. *Contributions to Mineralogy and Petrology* **173**, 1.

Druitt, T. H., Mercier, M., Florentin, L., Deloule, E., Cluzel, N., Flaherty, T., Médard, E. & Cadoux, A. (2016). Magma Storage and Extraction Associated with Plinian and Interplinian Activity at Santorini Caldera (Greece). *Journal of Petrology* **57**, 461–494.

Duan, Z. & Zhang, Z. (2006). Equation of state of the H2O, CO2, and H2O–CO2 systems up to 10 GPa and 2573.15K: Molecular dynamics simulations with ab initio potential surface. *Geochimica et Cosmochimica Acta* **70**, 2311–2324.

Esposito, R., Bodnar, R. J., Danyushevsky, L. V., De Vivo, B., Fedele, L., Hunter, J., Lima, A. & Shimizu, N. (2011). Volatile Evolution of Magma Associated with the Solchiaro Eruption in the Phlegrean Volcanic District (Italy). *Journal of Petrology* **52**, 2431–2460.

Famin, V., Welsch, B., Okumura, S., Bachèlery, P. & Nakashima, S. (2009). Three differentiation stages of a single magma at Piton de la Fournaise volcano (Reunion hot spot). *Geochemistry, Geophysics, Geosystems* **10**.

Field, L., Blundy, J., Brooker, R. A., Wright, T. & Yirgu, G. (2012). Magma storage conditions beneath Dabbahu Volcano (Ethiopia) constrained by petrology, seismicity and satellite geodesy. *Bulletin of Volcanology* **74**, 981–1004.

Gansecki, C., Lee, R. L., Shea, T., Lundblad, S. P., Hon, K. & Parcheta, C. (2019). The tangled tale of Kīlauea’s 2018 eruption as told by geochemical monitoring. *Science*. American Association for the Advancement of Science **366**, eaaz0147.

Gennaro, E., Iacono-Marziano, G., Paonita, A., Rotolo, S. G., Martel, C., Rizzo, A. L., Pichavant, M. & Liotta, M. (2019). Melt inclusions track melt evolution and degassing of Etnean magmas in the last 15 ka. *Lithos* **324–325**, 716–732.

Ghiorso, M. S. & Gualda, G. A. R. (2015). An H2O–CO2 mixed fluid saturation model compatible with rhyolite-MELTS. *Contributions to Mineralogy and Petrology* **169**, 53.

Gleeson, M. L. M., Gibson, S. A. & Stock, M. J. (2022). Constraints on the behaviour and content of volatiles in Galápagos magmas from melt inclusions and nominally anhydrous minerals. *Geochimica et Cosmochimica Acta* **319**, 168–190.

Hansteen, T. H. & Klügel, A. (2008). Fluid Inclusion Thermobarometry as a Tracer for Magmatic Processes. *Reviews in Mineralogy and Geochemistry* **69**, 143–177.

Harris, D. M. & Anderson Jr, A. T. (1983). Concentrations, sources, and losses of H2O, CO2, and S in Kilauean basalt. *Geochimica et Cosmochimica Acta*. Elsevier **47**, 1139–1150.

Hartley, M. E., Maclennan, J., Edmonds, M. & Thordarson, T. (2014). Reconstructing the deep CO2 degassing behaviour of large basaltic fissure eruptions. *Earth and Planetary Science Letters* **393**, 120–131.

Hauri, E. H., Maclennan, J., McKenzie, D., Gronvold, K., Oskarsson, N. & Shimizu, N. (2017). CO2 content beneath northern Iceland and the variability of mantle carbon. *Geology* **46**, 55–58.

Hauri, E., Plank, T., Fischer, T. P., Tamura, Y. & Ishizuka, O. (2021). Melt Inclusion data from the Marianas and Izu volcanic arcs, and Mariana Trough back-arc basin. https://ecl.earthchem.org/view.php?id=2036: EARTHCHEM.

Head, E. M., Shaw, A. M., Wallace, P. J., Sims, K. W. W. & Carn, S. A. (2011). Insight into volatile behavior at Nyamuragira volcano (D.R. Congo, Africa) through olivine-hosted melt inclusions. *Geochemistry, Geophysics, Geosystems* **12**.

Helo, C., Longpré, M.-A., Shimizu, N., Clague, D. A. & Stix, J. (2011). Explosive eruptions at mid-ocean ridges driven by CO2-rich magmas. *Nature Geoscience*. Nature Publishing Group **4**, 260–263.

Helz, R. T. & Thornber, C. R. (1987). Geothermometry of Kilauea Iki lava lake, Hawaii. *Bulletin of Volcanology* **49**, 651–668.

Hernandez Nava, A., Black, B. A., Gibson, S. A., Bodnar, R. J., Renne, P. R. & Vanderkluysen, L. (2021). Reconciling early Deccan Traps CO2 outgassing and pre-KPB global climate. *Proceedings of the National Academy of Sciences*. Proceedings of the National Academy of Sciences **118**, e2007797118.

Hudgins, T. R., Mukasa, S. B., Simon, A. C., Moore, G. & Barifaijo, E. (2015). Melt inclusion evidence for CO2-rich melts beneath the western branch of the East African Rift: implications for long-term storage of volatiles in the deep lithospheric mantle. *Contributions to Mineralogy and Petrology* **169**, 46.

Iacovino, K., Matthews, S., Wieser, P. E., Moore, G. M. & Bégué, F. (2021). VESIcal Part I: An Open-Source Thermodynamic Model Engine for Mixed Volatile (H2O-CO2) Solubility in Silicate Melts. *Earth and Space Science* **8**, e2020EA001584.

Iddon, F. & Edmonds, M. (2020). Volatile-Rich Magmas Distributed Through the Upper Crust in the Main Ethiopian Rift. *Geochemistry, Geophysics, Geosystems* **21**, e2019GC008904.

Jarosewich, E., Nelen, J. A. & Norberg, J. A. (1980). Reference samples for electron microprobe analysis. *Geostandards Newsletter*. Wiley Online Library **4**, 43–47.

Johnson, E. R., Wallace, P. J., Delgado Granados, H., Manea, V. C., Kent, A. J. R., Bindeman, I. N. & Donegan, C. S. (2009). Subduction-related Volatile Recycling and Magma Generation beneath Central Mexico: Insights from Melt Inclusions, Oxygen Isotopes and Geodynamic Models. *Journal of Petrology* **50**, 1729–1764.

Kelley, K. A. & Cottrell, E. (2009). Water and the Oxidation State of Subduction Zone Magmas. *Science*. American Association for the Advancement of Science **325**, 605–607.

Kelley, K. A., Plank, T., Newman, S., Stolper, E. M., Grove, T. L., Parman, S. & Hauri, E. H. (2010). Mantle Melting as a Function of Water Content beneath the Mariana Arc. *Journal of Petrology* **51**, 1711–1738.

Koleszar, A. M., Saal, A. E., Hauri, E. H., Nagle, A. N., Liang, Y. & Kurz, M. D. (2009). The volatile contents of the Galapagos plume; evidence for H2O and F open system behavior in melt inclusions. *Earth and Planetary Science Letters*. Elsevier **287**, 442–452.

Lerner, A. H. *et al.* (2021). The petrologic and degassing behavior of sulfur and other magmatic volatiles from the 2018 eruption of Kīlauea, Hawaiʻi: melt concentrations, magma storage depths, and magma recycling. *Bulletin of Volcanology*. Springer **83**, 1–32.

Lerner, A. H., Sublett, D. M., Wallace, P. J., Cauley, C. & Bodnar, R. J. (2024). Insights into magma storage depths and eruption controls at Kīlauea Volcano during explosive and effusive periods of the past 500 years based on melt and fluid inclusions. *Earth and Planetary Science Letters* **628**, 118579.

Lloyd, A. S., Plank, T., Ruprecht, P., Hauri, E. H. & Rose, W. (2013). Volatile loss from melt inclusions in pyroclasts of differing sizes. *Contributions to Mineralogy and Petrology* **165**, 129–153.

Longpré, M.-A., Stix, J., Klügel, A. & Shimizu, N. (2017). Mantle to surface degassing of carbon- and sulphur-rich alkaline magma at El Hierro, Canary Islands. *Earth and Planetary Science Letters* **460**, 268–280.

Manzini, M., Bouvier, A.-S., Baumgartner, L. P., Rose-Koga, E. F., Schiano, P. & Shimizu, N. (2019). Grain scale processes recorded by oxygen isotopes in olivine-hosted melt inclusions from two MORB samples. *Chemical Geology* **511**, 11–20.

Métrich, N., Zanon, V., Créon, L., Hildenbrand, A., Moreira, M. & Marques, F. O. (2014). Is the ‘Azores Hotspot’ a Wetspot? Insights from the Geochemistry of Fluid and Melt Inclusions in Olivine of Pico Basalts. *Journal of Petrology* **55**, 377–393.

Miller, W. G. R., Maclennan, J., Shorttle, O., Gaetani, G. A., Le Roux, V. & Klein, F. (2019). Estimating the carbon content of the deep mantle with Icelandic melt inclusions. *Earth and Planetary Science Letters* **523**, 115699.

Moore, L. R. *et al.* (2015). Bubbles matter: An assessment of the contribution of vapor bubbles to melt inclusion volatile budgets. *American Mineralogist*. Mineralogical Society of America **100**, 806–823.

Moore, L. R., Gazel, E. & Bodnar, R. J. (2021). The volatile budget of Hawaiian magmatism: Constraints from melt inclusions from Haleakala volcano, Hawaii. *Journal of Volcanology and Geothermal Research* **410**, 107144.

Moore, L. R., Mironov, N., Portnyagin, M., Gazel, E. & Bodnar, R. J. (2018). Volatile contents of primitive bubble-bearing melt inclusions from Klyuchevskoy volcano, Kamchatka: Comparison of volatile contents determined by mass-balance versus experimental homogenization. *Journal of Volcanology and Geothermal Research* **358**, 124–131.

Mormone, A., Piochi, M., Bellatreccia, F., De Astis, G., Moretti, R., Ventura, G. D., Cavallo, A. & Mangiacapra, A. (2011). A CO2-rich magma source beneath the Phlegraean Volcanic District (Southern Italy): Evidence from a melt inclusion study. *Chemical Geology* **287**, 66–80.

Myers, M. L., Geist, D. J., Rowe, M. C., Harpp, K. S., Wallace, P. J. & Dufek, J. (2014). Replenishment of volatile-rich mafic magma into a degassed chamber drives mixing and eruption of Tungurahua volcano. *Bulletin of Volcanology* **76**, 872.

Plechov, P., Blundy, J., Nekrylov, N., Melekhova, E., Shcherbakov, V. & Tikhonova, M. S. (2015). Petrology and volatile content of magmas erupted from Tolbachik Volcano, Kamchatka, 2012–13. *Journal of Volcanology and Geothermal Research* **307**, 182–199.

Putirka, K. D. (2008). Thermometers and barometers for volcanic systems. *Reviews in mineralogy and geochemistry*. Mineralogical Society of America **69**, 61–120.

Rasmussen, D. J., Kyle, P. R., Wallace, P. J., Sims, K. W. W., Gaetani, G. A. & Phillips, E. H. (2017). Understanding Degassing and Transport of CO2-rich Alkalic Magmas at Ross Island, Antarctica using Olivine-Hosted Melt Inclusions. *Journal of Petrology* **58**, 841–861.

Rasmussen, D. J. & Plank, T. (2021). Melt inclusion data for the central-eastern Aleutian volcanoes. https://ecl.earthchem.org/view.php?id=1873: EARTHCHEM.

Rasmussen, D. J., Plank, T., Cottrell, E., Johansson, A., Lehnert, K. & Hauri, E. (2022). DCO-EarthChem Melt Inclusion Expert Dataset. https://ecl.earthchem.org/view.php?id=2364: EARTHCHEM.

Ribeiro, J. M., Stern, R. J., Kelley, K. A., Shaw, A. M., Martinez, F. & Ohara, Y. (2015). Composition of the slab-derived fluids released beneath the Mariana forearc: Evidence for shallow dehydration of the subducting plate. *Earth and Planetary Science Letters* **418**, 136–148.

Roberge, J., Delgado-Granados, H. & Wallace, P. J. (2009). Mafic magma recharge supplies high CO2 and SO2 gas fluxes from Popocatépetl volcano, Mexico. *Geology* **37**, 107–110.

Robidoux, P., Frezzotti, M. L., Hauri, E. H. & Aiuppa, A. (2018). Shrinkage Bubbles: The C–O–H–S Magmatic Fluid System at San Cristóbal Volcano. *Journal of Petrology* **59**, 2093–2122.

Robidoux, P., Rotolo, S. G., Aiuppa, A., Lanzo, G. & Hauri, E. H. (2017). Geochemistry and volatile content of magmas feeding explosive eruptions at Telica volcano (Nicaragua). *Journal of Volcanology and Geothermal Research* **341**, 131–148.

Roggensack, K. (2001a). Unraveling the 1974 eruption of Fuego volcano (Guatemala) with small crystals and their young melt inclusions. *Geology* **29**, 911–914.

Roggensack, K. (2001b). Sizing up crystals and their melt inclusions: a new approach to crystallization studies. *Earth and Planetary Science Letters* **187**, 221–237.

Roggensack, K., Hervig, R. L., McKnight, S. B. & Williams, S. N. (1997). Explosive basaltic volcanism from Cerro Negro volcano: influence of volatiles on eruptive style. *Science*. American Association for the Advancement of Science **277**, 1639–1642.

Rose-Koga, E. F., Koga, K. T., Schiano, P., Le Voyer, M., Shimizu, N., Whitehouse, M. J. & Clocchiatti, R. (2012). Mantle source heterogeneity for South Tyrrhenian magmas revealed by Pb isotopes and halogen contents of olivine-hosted melt inclusions. *Chemical Geology* **334**, 266–279.

Ruscitto, D. M., Wallace, P. J., Johnson, E. R., Kent, A. J. R. & Bindeman, I. N. (2010). Volatile contents of mafic magmas from cinder cones in the Central Oregon High Cascades: Implications for magma formation and mantle conditions in a hot arc. *Earth and Planetary Science Letters* **298**, 153–161.

Ruscitto, D. M., Wallace, P. J. & Kent, A. J. R. (2011). Revisiting the compositions and volatile contents of olivine-hosted melt inclusions from the Mount Shasta region: implications for the formation of high-Mg andesites. *Contributions to Mineralogy and Petrology* **162**, 109–132.

Ruth, D. C. S., Cottrell, E., Cortés, J. A., Kelley, K. A. & Calder, E. S. (2016). From Passive Degassing to Violent Strombolian Eruption: the Case of the 2008 Eruption of Llaima Volcano, Chile. *Journal of Petrology* **57**, 1833–1864.

Ryan, M. P. (1987). The elasticity and contractancy of Hawaiian olivine tholeiite, and its role in the stability and structural evolution of sub-caldera magma reservoirs and rift systems. In Volcanism in Hawaii. *US Geol. Surv. Prof. Pap.* **1350**, 1395–1447.

Saal, A. E., Hauri, E. H., Langmuir, C. H. & Perfit, M. R. (2002). Vapour undersaturation in primitive mid-ocean-ridge basalt and the volatile content of Earth’s upper mantle. *Nature*. Nature Publishing Group **419**, 451–455.

Sadofsky, S. J., Portnyagin, M., Hoernle, K. & van den Bogaard, P. (2008). Subduction cycling of volatiles and trace elements through the Central American volcanic arc: evidence from melt inclusions. *Contributions to Mineralogy and Petrology* **155**, 433–456.

Schipper, C. I., White, J. D. L. & Houghton, B. F. (2011). Textural, geochemical, and volatile evidence for a Strombolian-like eruption sequence at Lō`ihi Seamount, Hawai`i. *Journal of Volcanology and Geothermal Research* **207**, 16–32.

Shaw, A. M., Behn, M. D., Humphris, S. E., Sohn, R. A. & Gregg, P. M. (2010). Deep pooling of low degree melts and volatile fluxes at the 85°E segment of the Gakkel Ridge: Evidence from olivine-hosted melt inclusions and glasses. *Earth and Planetary Science Letters* **289**, 311–322.

Sides, I., Edmonds, M., Maclennan, J., Houghton, B. F., Swanson, D. A. & Steele-MacInnis, M. J. (2014). Magma mixing and high fountaining during the 1959 Kīlauea Iki eruption, Hawai ‘i. *Earth and Planetary Science Letters*. Elsevier **400**, 102–112.

Span, R. & Wagner, W. (1996). A new equation of state for carbon dioxide covering the fluid region from the triple‐point temperature to 1100 K at pressures up to 800 MPa. *Journal of physical and chemical reference data*. American Institute of Physics for the National Institute of Standards and … **25**, 1509–1596.

Sterner, S. M. & Pitzer, K. S. (1994). An equation of state for carbon dioxide valid from zero to extreme pressures. *Contributions to Mineralogy and Petrology*. Springer **117**, 362–374.

Taracsák, Z., Hartley, M. E., Burgess, R., Edmonds, M., Iddon, F. & Longpré, M.-A. (2019). High fluxes of deep volatiles from ocean island volcanoes: Insights from El Hierro, Canary Islands. *Geochimica et Cosmochimica Acta* **258**, 19–36.

Venugopal, S., Moune, S. & Williams-Jones, G. (2016). Investigating the subsurface connection beneath Cerro Negro volcano and the El Hoyo Complex, Nicaragua. *Journal of Volcanology and Geothermal Research* **325**, 211–224.

Venugopal, S., Moune, S., Williams-Jones, G., Druitt, T., Vigouroux, N., Wilson, A. & Russell, J. K. (2020a). Two distinct mantle sources beneath the Garibaldi Volcanic Belt: Insight from olivine-hosted melt inclusions. *Chemical Geology* **532**, 119346.

Venugopal, S., Moune, S., Williams-Jones, G., Druitt, T., Vigouroux, N., Wilson, A. & Russell, J. K. (2020b). Two distinct mantle sources beneath the Garibaldi Volcanic Belt: Insight from olivine-hosted melt inclusions. *Chemical Geology* **532**, 119346.

Vigouroux, N., Wallace, P. J. & Kent, A. J. R. (2008). Volatiles in High-K Magmas from the Western Trans-Mexican Volcanic Belt: Evidence for Fluid Fluxing and Extreme Enrichment of the Mantle Wedge by Subduction Processes. *Journal of Petrology* **49**, 1589–1618.

Wade, J. A., Plank, T., Melson, W. G., Soto, G. J. & Hauri, E. H. (2006). The volatile content of magmas from Arenal volcano, Costa Rica. *Journal of Volcanology and Geothermal Research* **157**, 94–120.

Wallace, P. J., Kamenetsky, V. S. & Cervantes, P. (2015). Melt inclusion CO2 contents, pressures of olivine crystallization, and the problem of shrinkage bubbles. *American Mineralogist*. GeoScienceWorld **100**, 787–794.

Walowski, K. J., Kirstein, L. A., De Hoog, J. C. M., Elliott, T. R., Savov, I. P. & Jones, R. E. (2019). Investigating ocean island mantle source heterogeneity with boron isotopes in melt inclusions. *Earth and Planetary Science Letters* **508**, 97–108.

Walowski, K. J., Wallace, P. J., Clynne, M. A., Rasmussen, D. J. & Weis, D. (2016). Slab melting and magma formation beneath the southern Cascade arc. *Earth and Planetary Science Letters* **446**, 100–112.

Wanless, V. D., Behn, M. D., Shaw, A. M. & Plank, T. (2014). Variations in melting dynamics and mantle compositions along the Eastern Volcanic Zone of the Gakkel Ridge: insights from olivine-hosted melt inclusions. *Contributions to Mineralogy and Petrology* **167**, 1005.

Wanless, V. D. & Shaw, A. M. (2012). Lower crustal crystallization and melt evolution at mid-ocean ridges. *Nature Geoscience*. Nature Publishing Group **5**, 651–655.

Wanless, V. D., Shaw, A. M., Behn, M. D., Soule, S. A., Escartín, J. & Hamelin, C. (2015). Magmatic plumbing at Lucky Strike volcano based on olivine-hosted melt inclusion compositions. *Geochemistry, Geophysics, Geosystems* **16**, 126–147.

Wieser, P. E. *et al.* (2021). Reconstructing Magma Storage Depths for the 2018 Kı̄lauean Eruption From Melt Inclusion CO2 Contents: The Importance of Vapor Bubbles. *Geochemistry, Geophysics, Geosystems* **22**, e2020GC009364.

Wieser, P. E. & DeVitre, C. (2024). DiadFit: An open-source Python3 tool for peak fitting of Raman data from silicate melts and CO2 fluids. *Volcanica* **7**, 335–359.

Wieser, P. E., Gleeson, M., Matthews, S., DeVitre, C. L. & Gazel, E. (2023a). Determining the Pressure – Temperature – Composition (P-T-X) conditions of magma storage. EarthArXiv.

Wieser, P. E., Kent, A. J. R., Till, C. B., Donovan, J., Neave, D. A., Blatter, D. L. & Krawczynski, M. J. (2023b). Barometers Behaving Badly I: Assessing the Influence of Analytical and Experimental Uncertainty on Clinopyroxene Thermobarometry Calculations at Crustal Conditions. *Journal of Petrology* **64**, egac126.

Wieser, P. E., Kent, A., Till, C. & Abers, G. (2023c). Geophysical and Geochemical Constraints on Magma Storage Depths along the Cascade Arc: Knowns and Unknowns. EarthArXiv.

Wieser, P., Petrelli, M., Lubbers, J., Wieser, E., Ozaydin, S., Kent, A. & Till, C. (2022). Thermobar: An open-source Python3 tool for thermobarometry and hygrometry. *Volcanica* **5**, 349–384.

Wong, K., Ferguson, D., Wieser, P., Morgan, D., Edmonds, M., Tadesse, A. Z., Yirgu, G., Harvey, J. & Hammond, S. (2023). Focused Mid-Crustal Magma Intrusion During Continental Break-Up in Ethiopia. *Geophysical Research Letters* **50**, e2023GL103257.

Wysoczanski, R. J., Handler, M. R., Schipper, C. I., Leybourne, M. I., Creech, J., Rotella, M. D., Nichols, A. R. L., Wilson, C. J. N. & Stewart, R. B. (2012). The Tectonomagmatic Source of Ore Metals and Volatile Elements in the Southern Kermadec Arc. *Economic Geology* **107**, 1539–1556.

Yoshimura, S. (2023). Carbon dioxide and water in the crust. Part 1: Equation of state for the fluid. *Journal of Mineralogical and Petrological Sciences* **118**, 221224a.

Zimmer, M. M. (2009). *Water in Aleutian Magmas: its origins in the subduction zone and its effects on magma evolution*. ProQuest.

Zimmer, M. M. *et al.* (2010). The Role of Water in Generating the Calc-alkaline Trend: New Volatile Data for Aleutian Magmas and a New Tholeiitic Index. *Journal of Petrology* **51**, 2411–2444.