Appendix 2. Extended Methods

Samples and preparation

Figure 1. Sample preparation equipment and examples of impregnated lava dome samples and thick sections.

Vacuum impregnation

Vacuum impregnation was performed on pumice and lava dome samples to keep fractured and shattered quartz intact and to reduce plucking. Sample blocks (3" x 2" x 1") were cut using a 0.635 mm Hillquist trim saw on a Hillquist thin section machine. Blocks were oven-dried for 12 hours and placed inside a 3" x 2" x 1" plastic mold (**Fig. 1**). Ultra-low viscosity L.R. White Resin (hard grade acrylic resin) was added incrementally to blocks using a low vacuum of ~200 kPa and occasionally 300–400 kPa between each addition. Once vacuum impregnation was complete, lids were put on sample molds to reduce oxygen exposure to resin-filled blocks. The impregnated blocks were then placed in an oven for 20–24 hours at ~60–65°C to cure.

Slide mounting

The bottoms of plastic molds holding impregnated sample blocks were hand-ground on a glass plate with 120 grit (silicon carbide), followed by 220, 400, and 600 grit. These steps were taken to produce a smooth surface for sufficient surface tension to hold the blocks on the ceramic plate of the thin section machine arm. The bottoms of the molds were cut off to expose rock.

The following procedure was carried out for each consecutive cut of sample blocks (**Fig. 1**) during serial sectioning:

(1) Wet blocks were dried in an oven for ~2 hours.

(2) Because resin impregnation does not fill all matrix pore space, hot block surfaces were coated with Hillquist *Part C + Part D* thin section epoxy to prevent or reduce crystal plucking during grinding and polishing. After *C + D* epoxy was applied to block surfaces, it was left for a few minutes to fill pore space. Excess epoxy was wiped off, and blocks were heated on a hot plate for ~15 minutes to cure the thin coat of epoxy.
(3) Block surfaces were ground using 400 grit on a lap wheel, followed by 600 grit by hand on a glass plate in preparation for slide mounting.
(4) Wet blocks were oven-dried for ~2 hours.
(5) Hillquist *Part A + Part B* thin section epoxy was applied to hot block surfaces. Heated surfaces allowed trapped air bubbles to escape from the thicker *A + B* epoxy mix prior to slide mounting.
(6) Ward's 3" x 2" glass thin section slides were mounted on block surfaces. Warm blocks were left to sit for ~10 minutes to prevent drawing in air bubbles. The blocks were then placed onto a hot plate to accelerate curing.

Serial sectioning

The desired thickness of each serial slice was ~200 microns in order to prevent significant loss of crystal interior information and maintain enough thickness for LA-ICP-MS analysis. To aid in obtaining this thickness, a 0.635 mm Hillquist saw was put on the Hillquist machine and the thin section arm was moved closer to the saw.

Complete adhesion of glass slides to the ceramic thin section arm plate was critical due to the weight of the blocks. Block size and the thinness of the saw resulted in minor issues with wedged cuts. The thickness of single sections typically ranges from ~150–400 microns (**Fig. 1**). Sections were dried on a hotplate, coated with *C + D* Hillquist epoxy to fill in any pore space, and wiped with Kim wipes. Sections were ground on a lap wheel using 400 grit, followed by hand-grinding using 600 and 1000 grits on a glass plate to remove *C +D* epoxy and obtain a low-polish.

Polishing

Sections were polished by hand with a custom holder using a Struers lap wheel machine. Polishing mediums included a Piano-2000 diamond disc, followed by 3 µm diamond suspension, 1µm diamond suspension, and colloidal silica suspension.

Secondary electron (SE) imaging

Secondary electron images were taken using a FEI Philips XL 40 ESEM at Michigan Tech. Loose quartz crystals were adhered to carbon tape on top of a glass slide. A ~25 nm carbon coat was applied. The SEM sample stage was set to provide a 10 mm working distance. The SEM was operated at a low vacuum with an accelerating voltage of 10 kV. Images were collected using a spot size of 4 and dwell time of 50 µs.

Cathodoluminescence (CL) imaging

Digital CL imaging was performed using panchromatic CL and Rainbow CL detectors attached to a TESCAN VEGA3 XMU VP scanning electron microscope (SEM) at UCLA. Prior to imaging, thick 3" x 2" polished sections were immersed in isopropyl alcohol and sonicated to remove any remaining polishing medium from cracks. No carbon coating was applied. The sample stage was set at Z=20 mm, which provided a 33.7 mm working distance and 40x magnification optimal for viewing large areas (~7

mm diameter). The SEM was operated at a low vacuum (5–6 Pa) with an accelerating voltage and beam current of 20 kV and 20 nA, respectively, and set to resolution scan mode. High contrast and low brightness settings were ideal; however, settings required minor adjustments between each crystal and were recorded for each image. Variable CL emissions of other mineral phases surrounding quartz may account for the need to vary contrast and brightness from image to image. Recorded values of contrast and brightness remained fairly consistent between crystals and different samples. Image collection times varied between ~1 and 4 minutes depending on scan speed (6–8). Images were obtained between 768 x 828 pixel (110 ppi) and 1024 x 1104 pixel (146 ppi) resolutions at 16 bit depths, and were stored as TIF files.

Different types of CL artifacts may occur when imaging quartz. Common artifacts are dark rectangles in scanned areas, which result from extended exposure to the electron beam (Peppard et al. 2001). This artifact disappears with time once the electron beam has been removed. Melt inclusions or embayments underlying the polished surface may also increase or decrease CL emission (see Fig. 10 of the main text). Additionally, areas of anomalously high CL emission, typically near crystal margins or of entire fragments or regions, may be caused by a non-horizontal surface (i.e. a surface not orthogonal to the electron beam). Anomalous CL emission can also be gradational within crystal interiors, and thus may alternatively be the result of lattice defects. Other CL artifacts include (1) white bands or scan lines across crystals due to the 'bleeding over' of adjacent, high CL emission minerals, (2) small bright dots that result from minor charging of matrix glass material, and (3) minor distortions near the borders of images taken at the minimum magnification (40x in this study).

Electron Backscatter Diffraction (EBSD) analysis

Quartz clusters in YTT sections were analyzed using a HKL Nordlys II Detector and Channel 5 software (Oxford Instruments) on the TESCAN VEGA3 LMU SEM at Bowdoin College using methods similar to those of Beane and Wiebe (2012). Sections were polished by hand with a custom holder using a Struers polishing wheel and colloidal silica suspension. No carbon coating was applied. The sample stage was set at Z=21 mm with a 70° tilt. EBSD patterns were collected at an accelerating voltage of 20 kV and current of 20 nA under a vacuum of 15 Pa. Channel 5 acquisitions and indexing settings included 4 x 4 binning and 8 Kikuchi bands detected in EBSPs. Automatic EBSD mapping was performed at 50–100 μm step sizes; ~300–2300 data points are plotted for each crystal (see Fig. 8 in the main text). Indexed patterns were matched to known lattice parameters of α-quartz (*P321*) within the Channel 5 software HKL phase list, as all quartz presently represents this polymorph (Prior et al. 1999 and references therein). Average mean angular deviation (MAD) values for our data were 0.5–0.8. Precision of the data is ~1° based upon the number of bands detected and experimental work of Krieger-Lassen (1995). Using Channel 5 software, noise reduction was applied to raw orientation maps, and non- and mis-indexed points were replaced by the most common orientation of six neighboring pixels. No data exists for white areas that correspond to open fractures, embayments, or voids in Figure 8 of the main text. Pole figures for each EBSD map were generated using Mambo in Channel 5 software. Angular relations between corresponding crystallographic axes and corresponding poles to faces of grouped crystal units were measured manually in Mambo and in the Stereonet 8 program (Allmendinger et al. 2012; Cardozo and Allmendinger 2013). Measurements between poles corresponding to *c*-axes were replicated and indicate ~1–4° measurement errors (Brugger and Hammer 2015).

Quartz clusters in lava dome sections and one YTT sample were analyzed using Oxford Instruments HKL Nordlys II Detector and Channel 5 software on a JEOL JSM-7600F SEM at Nanyang

Technological University, Singapore. A ~15 nm carbon coat was applied. The sample stage was set at Z=26 mm with a 70° tilt. EBSD patterns were collected at an accelerating voltage of 30 kV and current of 175 µA under a vacuum of 8 Pa. Channel 5 acquisitions and indexing settings included 4 x 4 binning, 7–9 Kikuchi bands detected in EBSPs, and 1–10 µm step sizes for orientation maps. Areas mapped on individual crystal units were 15 x 20 µm and up to 30 x 50 µm. Small areas of crystal units were mapped rather than entire units due to the smaller sizes of some target clusters and to reduce analysis time. Indexing parameters and angle measurement procedures are the same as described for YTT quartz analyses. Average mean angular deviation (MAD) values for this data were 0.2–0.9. Measurements between poles corresponding to *c*-axes were replicated and indicate ~1–3° measurement errors (Brugger and Hammer 2015). One analysis [T-20 (2.9)] was duplicated and shows consistent results between the two instruments used.

X-ray Computed Tomography (X-ray CT)

Tomographic imaging was performed using a NSI ImagiX microCT system at Vanderbilt University. Descriptions and details of X-ray CT methods and set up can be found in Rivers et al. (1999), Gualda and Rivers (2006), Pamukcu and Gualda (2010), and Pamukcu et al. (2012). Incident beam energies were between 80 and 90 kV and 90 µA. Sample rotations were 360°. Resolutions of tomograms represent a voxel size of 29.4 x 29.4 x 29.4 microns.

Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS)

Quartz trace element concentrations were collected using a 193 nm Resonetics Resolution 155 excimer laser ablation system coupled to a Thermo Scientific Element XR sector field mass spectrometer at ETH Zürich. Quartz was ablated using a spot size of 29 µm, and 30 kV beam energy at 5 Hz for 40 s after 30 s of gas blank acquisition. Elements analyzed for are listed in the main text.

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