Under the volcano: Tracing the path of eruptible arc magmas

Daniel Rasmussen (National Museum of Natural History, Smithsonian Institution) and
Megan Newcombe (University of Maryland)

As you read this article, there are 40-50 volcanoes erupting (www.volcano.si.edu). These eruptions have profound implications for hazards (Cameron et al. 2018; Roman and Cashman 2018; Power et al. 2020), formation and evolution of crust (Cai et al. 2015; Morris et al. 2019), climate and volatile cycling (Kelemen and Manning 2015; Aiuppa et al. 2019; Fischer et al. 2019), and ore deposits (Zajacz et al. 2010; Wilkinson 2013; Blundy et al. 2015), and they enable Earth Scientists to peer deep into Earth (Turner et al. 2016; Till et al. 2019). Understanding the volcanic process is of fundamental importance, and the study of the architecture of crustal magmatic systems is key to achieving this goal. Magmatic plumbing systems may be understood, in part, from investigation of magma storage depth, which relates closely to eruptibility (Moran et al. 2011; Degruyter and Huber 2014; Huber et al. 2019), crustal structure (Janiszewski et al. 2013; Crosbie et al. 2019), and magmatic differentiation (Zimmer et al. 2010; Husen et al. 2016). Because many magmatic systems are thought to be dynamic in nature, determining the timescales of magmatic processes is also crucial to understanding magmatic plumbing systems.

In the decade since the inception of GeoPRISMS, we have significantly improved our understanding of the depths and rates of magmatic processes occurring in the crust. Large-scale research platforms have enabled data collection at an unprecedented level of detail, and have facilitated collaborations across disciplines and institutions. One prime example is the joint GeoPRISMS and EarthScope iMUSH experiment (Hansen et al. 2016; Kiser et al. 2016; Kiser et al. 2019; Ulberg et al. 2020). Another is the set of 2015 field campaigns in the Aleutians, which brought together scientists from GeoPRISMS, the Alaska Volcano Observatory, and the Deep Carbon Observatory. Concurrent with large-scale community experiments have been advancements in methods of data collection and analysis. Novel seismic experiments have been conducted, such as the deployment of large geophone arrays (Hansen and Schmandt 2015; Glasgow et al. 2018), and we are now able to perform full-waveform inversions of infrasonic data with topography, thereby enabling estimates of volume flow rate (Kim et al. 2015; Fee et al. 2017b). The development of Multi-component Gas Analyzer System (MultiGAS) instruments enables the measurement of different gas species simultaneously, ushering in a new era for studies of magmatic systems (Aiuppa et al. 2005; Shinohara 2005).

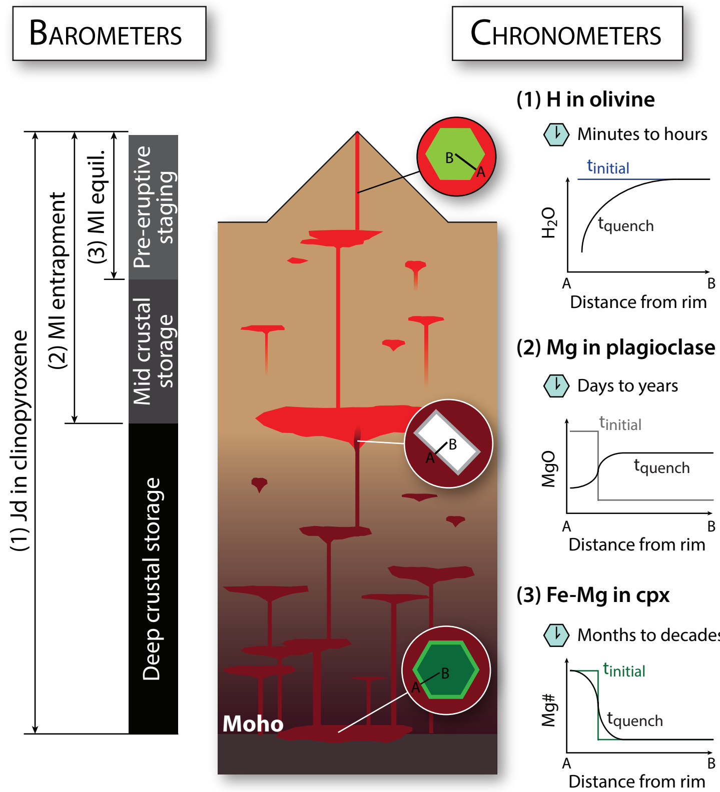


Figure 1. Combined chronometry and barometry approach to understanding magmatic plumbing systems.

Improved microanalytical techniques now enable the high-precision analysis of major, volatile, and trace elements at the micron scale (Le Voyer et al. 2014; Lloyd et al. 2014; Saunders et al. 2014; Ubide et al. 2015). Crystal clocks, which are geochemical tools based on the principle of diffusion, have come of age, and are increasingly used for determining rates of magmatic processes over timescales of minutes to thousands of years (Rosen 2016), and our geobarometric tools have been honed (Fig. 1; Neave and Putirka 2017; Rasmussen et al. 2020). The growing body of observations using such techniques in the study of experimental and natural systems has been codified by recent reviews (Bergantz et al. 2015; Cashman et al. 2017). Together, we are now able to peer into magmatic plumbing systems and place magmas in both time and space. In this article we highlight a few of the areas of significant progress from GeoPRISMS and related research, and we identify areas for future work. We focus on arc magmatism, as arcs are where most subaerial volcanism occurs.

What is the rate of mantle-derived magma production at arcs?

The supply of mantle-derived magma ultimately drives volcanic eruptions (Poland et al. 2012; Sides et al. 2014) and controls crustal production at arcs (Vogt et al. 2012; Till et al. 2019). Quantification of the rate of magma supply from the mantle to the base of the crust requires estimations of erupted and intruded magma volumes, and rates of crustal erosion. These parameters are notoriously difficult to estimate, but much progress has been made via the study of exposed crustal sections (DeBari and Greene 2011; Kay et al. 2019; Morris et al. 2019), lower-crustal xenoliths (Rudnick and Goldstein 1990; Yogodzinski and Kelemen 2007) and from seismic surveys (Shillington et al. 2004; Janiszewski et al. 2013; Shillington et al. 2013). Radiometric dating can be combined with estimates of crustal composition and structure to estimate time-averaged magma supply rates (Jicha et al. 2006; Jicha and Jagoutz 2015; Ducea et al. 2017). Alternatively, time-averaged magma supply rates can be estimated by pairing measurements of SO_2 fluxes from volcanoes with estimates of primary magma sulfur concentrations derived from analyses of primitive melt inclusions (Werner et al. 2020). Estimates of magma supply rates can then be combined with estimates of extruded magma volumes (Werner et al. 2017) to calculate the ratio of intruded to extruded magma volume; e.g., Werner et al. (2020) use this approach to estimate an intrusive to extruded magma volume ratio of 13:1 at Mt. Cleveland, Alaska.

What controls the rate of magma production at subduction zones? The age, temperature, incoming plate velocity, slab dip, and hydration state of the slab are all considered to be important factors (Syracuse and Abers 2006; van Keken et al. 2011). The spatio-temporal variability in magma supply rates and primitive melt compositions may manifest as along-arc volcanic variability. However, the relative importance of mantle versus crustal control of along-arc volcanic variability remains a frontier problem in subduction zone science (Till et al. 2019).

Where is magma stored and processed in the crust?

Prior to their eruption at the surface, mantle-derived magmas must travel through crustal plumbing systems. In the last decade, our ability to identify and characterize such regions has grown substantially. Geodetic methods have seen significant advancements, particularly in data collection (Ebmeier et al. 2019) and computational techniques (Anantrasirichai et al. 2019; Reath et al. 2019; Sun et al. 2019). New satellite technology, exemplified by Sentinel-1 and satellite constellations, offers improved coverage and repeat intervals, enabling large-scale studies of volcanoes (Ebmeier et al. 2013; Pritchard et al. 2018). New seismic methods have been developed, including shear-wave splitting analysis (Roman and Gardine 2013) and novel receiver function techniques (Janiszewski et al. 2020). Electrical conductivity methods have seen significant advancements (Laumonier et al. 2017). Geochemical tools for studying magma depth have also improved substantially. Perhaps the greatest advancement has been in the field of melt inclusions, with new methods to account for vapor bubble growth (Hartley et al. 2014; Mironov et al. 2015; Moore et al. 2015; Wallace et al. 2015; Rasmussen et al. 2020), increasing depth estimates by up to a factor of two (Rasmussen et al., 2020). Finally, multi-disciplinary studies of magma depth, perhaps the best means for progress, are becoming increasingly prevalent (Aiuppa et al. 2010; Rasmussen et al. 2018b; DeGrandpre and Le Mével 2019; Werner et al. 2020).

The first stage of crustal transport of mantle-derived melts may be storage in lower crustal processing zones, referred to as MASH (Melting, Assimilation, Storage, and Homogenization; Hildreth and Moorbath 1988) or hot zones (Annen et al. 2006). Here magmas may undergo an initial phase of differentiation. Typically, such regions are envisioned to occur in the lower crust because elevated temperatures make them more easily maintained over long timescales (Annen et al., 2006) and geochemical evidence may point to the lower crust (Hildreth and Moorbath, 1988). In recent years, this model has been expanded. Differentiation is often considered to occur at various depths in the crustal column (Putirka 2017), and magmatic systems that seamlessly span much of the length of the crust have been proposed (Cashman et al., 2017). However, evidence exists that underscores the importance of lower crustal storage in some locations. Evidence is strong in areas of thick crust, such as central Chile (Hildreth and Moorbath, 1988) and Taupo (Rocco et al. 2019). Additional evidence comes from studying exposed arc crustal sections, such as the Famatinian, Kohistan, and Talkeetna arcs (DeBari and Greene 2011; Walker Jr et al. 2015). As seismic and electromagnetic techniques improve, it is now possible to see through upper- and mid-crustal magma bodies into the lower crust and find evidence for deep zones of melt collection. Slow seismic and/or conductive anomalies, consistent with regions of melt accumulation, have been found at several locations, such as Mount St. Helens (Kiser et al. 2016; Bedrosian et al. 2018), Puna Plateau (Delph et al. 2017), and Cleveland volcano (Janiszewski et al. 2020). While our ability to identify such regions has grown, questions remain about the prevalence of such lower crustal processing zones, particularly in regions of relatively thin crust, such as island-arc settings.

The vast majority of magma storage regions identified with geophysical and geochemical techniques are in the mid to upper crust. A key area of recent focus has been studying magma storage regions below caldera systems. These systems tend to be characterized by shallow magma storage (<5 km below the surface); examples include Okmok (Hart et al. 2018; Miller et al. 2018), Taupo (Harmon et al. 2019), Fisher (Mann and Freymueller 2003), and Masaya (Stephens and Wauthier 2018). However, exceptions to shallow storage exist (DeGrandpre et al. 2017; Jiang et al. 2018; Gottsmann et al. 2020). Another area of focus has been understanding how magmatic plumbing systems evolve during the lead-up to eruption, demonstrating their dynamic nature (Kahl et al. 2015; Rasmussen et al. 2018b; Ruth et al. 2018; Albert et al. 2019). Effort has gone into compiling large databases of magma storage depth estimates (Chaussard and Amelung 2014), which most commonly identify storage regions between 2 and 8 km depth (Fig. 2; Rasmussen et al., 2019).

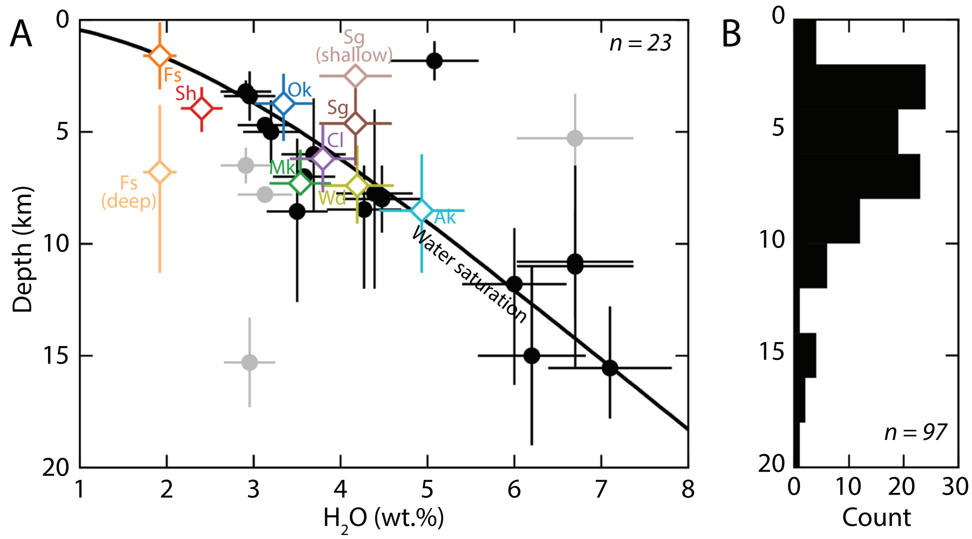


Figure 2. Comparison of magma storage depth and magmatic water content (Rasmussen et al., 2019). A) Scatterplot showing the relationship between magma storage depth and magmatic water content for arc volcanoes with good constraints on both (n = 23). The colored symbols indicate data for volcanoes in the central-eastern Aleutians, a GeoPRISMS focus site, volcanoes and black/gray markers show data for other arc volcanoes. Magma storage depths are estimates derived from geophysical approaches, compiled by Rasmussen et al. (2019). Some volcanoes have multiple regions of storage that have been identified, and in those cases, the storage region that occurs on the water saturation curve is shown with a dark-colored marker and the other is shown with a light-colored marker. Magmatic water contents are the maximum water contents measured in melt inclusions from each volcano. The water saturation curve was calculated using VolatileCalc (Newman and Lowenstern 2002), and pressure was converted to depth using the crustal density model in Rasmussen et al. (2020). These results indicate a sweet spot for the storage of arc magmas between 2 and 8 km depth. The positive correlation between magma storage depth and magmatic water content, and the close association of both with the water saturation curve, are consistent with water as a primary control of magma storage depth (Rasmussen et al., 2019). The central-eastern volcanoes include Fisher (Fs), Shishaldin (Sh), Okmok (Ok), Seguam (Sg), Cleveland (Cl), Makushin (Mk), and Westdahl (Wd). B) Histogram of magma storage depths compiled for arcs globally (n = 97).

Magma storage depths in less evolved (basalt-andesite) systems are closely linked to magmatic water content, consistent with magmatic water content influencing magma storage depth (Fig. 2; Zellmer et al. 2016; Rasmussen et al. 2019). Despite recent progress, several questions remain. The most significant progress will come from multidisciplinary studies, which often lead to improved understanding of not only depth but also process.

Over the last several years, there has been a paradigm shift in our understanding of magmatic plumbing systems. Gone are images of singular melt-rich pools in the mid- to upper-crust. Evidence for magma storage in crystal-rich mush zones is ubiquitous (Bachmann and Bergantz 2008; Marsh 2015), and such reservoirs are exemplified in some volcanoes in GeoPRISMS focus areas e.g., (Grant et al. 2019). Now, magmatic systems are commonly viewed with trans-crustal perspective in which mantle-derived magmas are processed in vertically extensive, low-melt fraction mush networks (Cashman et al. 2017). At some volcanoes, deep crustal seismicity has been linked to volcanic activity, demonstrating connectivity of magmatic plumbing systems (Power et al. 2004; Nichols et al. 2011).

How long does it take for magma to transit the crust?

A long-standing challenge has been determining the time required for magma to transit the crust. Recent advancements, particularly in the field of geochemistry, enable us to address this question. In the last decade, improved analytical methods and experimental data have unlocked the potential of crystal clocks, or diffusion chronometers (Costa and Morgan 2011; Costa et al. 2020).

The basic principle of these tools is that chemical or physical perturbations to a magmatic system may result in disequilibrium between the phases (e.g., melt, crystals) and initiate diffusion. Upon eruption, partially equilibrated crystals and melt erupt, freezing their chemical compositions in place. The extent of elibration can be determined by measuring the chemical composition, and through diffusion modeling, the time between the initial perturbation and the eruption can be determined. Often, this tool is used in conjunction with constraints from geophysics (Kahl et al., 2015; Rasmussen et al., 2018), geobarometry (Rasmussen et al., 2018; Ruth et al., 2018), and radiometric age dating (Cooper and Kent, 2014).

It is likely that primitive magmas erupted at the surface are biased towards shorter crustal transit times than more evolved magmas. Such magmas are commonly erupted at monogenetic cinder cones (Ruscitto et al. 2010; Salas et al. 2017; Rasmussen et al. 2018a; Pitcher and Kent 2019; Walowski et al. 2019). Thermo-chemical modeling has been used to argue that the preservation of high-forsterite olivine in basaltic magma requires rapid transport through the crust (Ruprecht and Plank, 2013), which may facilitate eruptions of high-forsterite olivines at cinder cones (Ruscitto et al. 2010; Salas et al. 2017; Walowski et al. 2019). Indeed, heightened seismicity occurs over timescales of weeks to years before eruptions of monogenetic cones, consistent with results from crystal clocks, suggesting relatively short crustal residence times for these magmas (Albert et al. 2016). Magmas that feed monogenetic cones in the Cascades are a current topic of study (Couperthwaite et al., 2020).

Relatively primitive magmas are also be erupted from some longer-lived edifices (Andrys et al. 2018). Short crustal transit times have also been found at these locations. Recent applications of diffusion chronometry to the crystal cargo of primitive magmas have addressed this question: Ni zonation patterns found in the cores of mantle-equilibrated olivine from Volcán Irazú in Costa Rica indicate mantle-derived melts can transit the crust in timescales of months to years (Ruprecht and Plank 2013), and even faster timescales of days have been found for the transit of magma from the Moho to the surface at Iceland (Mutch et al. 2019). Such timescales are similar to those of unrest and eruption (Passarelli and Brodsky, 2012), raising the possibility that magma supplied from the mantle can directly feed eruptions in some cases. We note that such short timescales (days to years) commonly determined for mafic systems may not tell the complete story. There is evidence that the residence time for crystals mobilized in basaltic eruptions may be significantly longer than the mobilization timescales (de Maisonneuve et al. 2016).

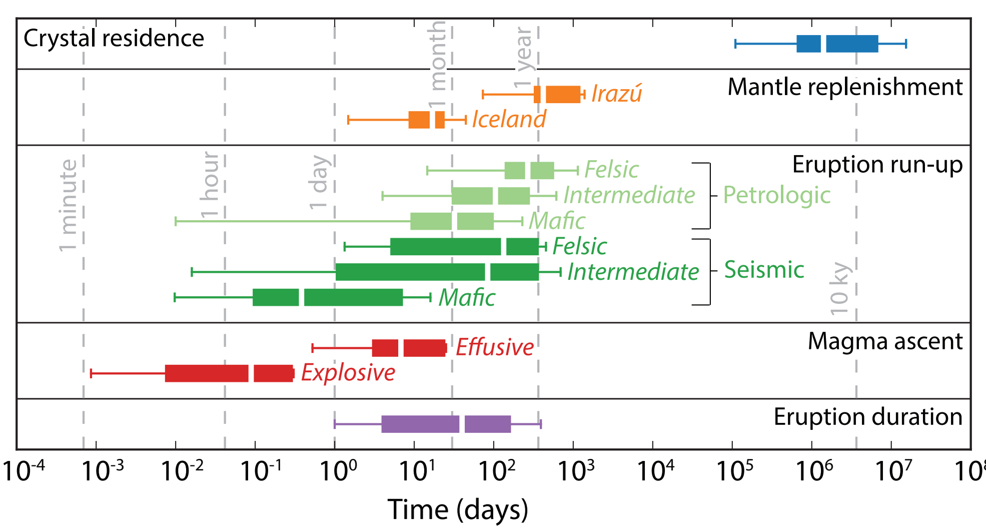
Evolved magmas erupted at long-lived edifices are likely subjected to much longer periods of stalling and processing. Combined studies of absolute crystal ages, determined radiometrically, and relative crystal ages, determined with diffusion-based approaches, indicate that crystal storage at long-repose interval volcanoes can last thousands to tens of thousands of years, but temperatures are above the solidus for only a small fraction of this time (Cooper and Kent 2014). At Taupo Volcanic Center, plagioclase crystallization ages are similar to maximum ages implied by diffusion chronometers, consistent with relatively long-term storage under warmer conditions (Schlieder et al. 2019). An alternative tool for understanding storage timescales, which is also based on chemical diffusion, is the analysis of melt inclusion morphology, which has been used to suggest timescales of tens to hundreds of years for the final assembly of large silicic magma bodies (Pamukcu et al., 2015). A relationship between magma composition and storage timescales is supported by the observation that volcanoes that erupt intermediate to evolved magma compositions generally have longer periods of repose than volcanoes erupting relatively primitive magmas (Passarelli and Brodsky, 2012).

What are the timescales of volcanic unrest and eruption?

Volcanic eruptions are often preceded by signs of unrest (Newhall et al. 2017) such as increased seismicity (Roman et al. 2006; Passarelli and Brodsky 2012), edifice inflation (Wnuk and Wauthier 2017; Pritchard et al. 2018), and changes in the composition and/or flux of volatile emissions (de Moor et al. 2016). In an ideal world, these signals of unrest could be used to predict the timing and size of volcanic eruptions; however, there are many challenges to this approach: Some volcanoes erupt with little-to-no warning (Fee et al. 2017a), while other volcanoes exhibit signs of unrest that are not followed by an eruption (Moran et al. 2011; Werner et al. 2011). Additionally, the timescale of volcanic unrest preceding an eruption varies from volcano to volcano (Passarelli and Brodsky 2012), and (in some cases) from eruption to eruption at the same edifice (Roult et al. 2012). With the compilation of large databases that document geophysical and geochemical records of volcanic unrest (Newhall et al. 2017), and the development of machine-learning techniques for automating the interpretation of such datasets (Malfante et al. 2018), we are poised to make great progress in our understanding of the processes and timescales of magmatic processes that occurring during the run-up to volcanic eruptions. A fundamental challenge is that the number of well-monitored eruptions we have is relatively small and the monitoring record is restricted to only the most recent eruptions. Petrologic approaches open up the possibility of studying geochemical signals of volcanic unrest throughout the entire rock record, thereby massively expanding the geographical and temporal range of eruptions that can be studied. The extension of such studies to present-day eruptions at well-monitored volcanoes allows for a powerful interdisciplinary approach that combines geophysical 'foresight' with a mechanistic, petrologic context.

One of the key areas of interest in the last several years has been the identification and study of magma recharge events (i.e., influxes of new magma to a shallow magma storage region), which are thought to be common eruption triggers (Martin et al. 2008).

Figure 3. Summary of crustal transport timescales.



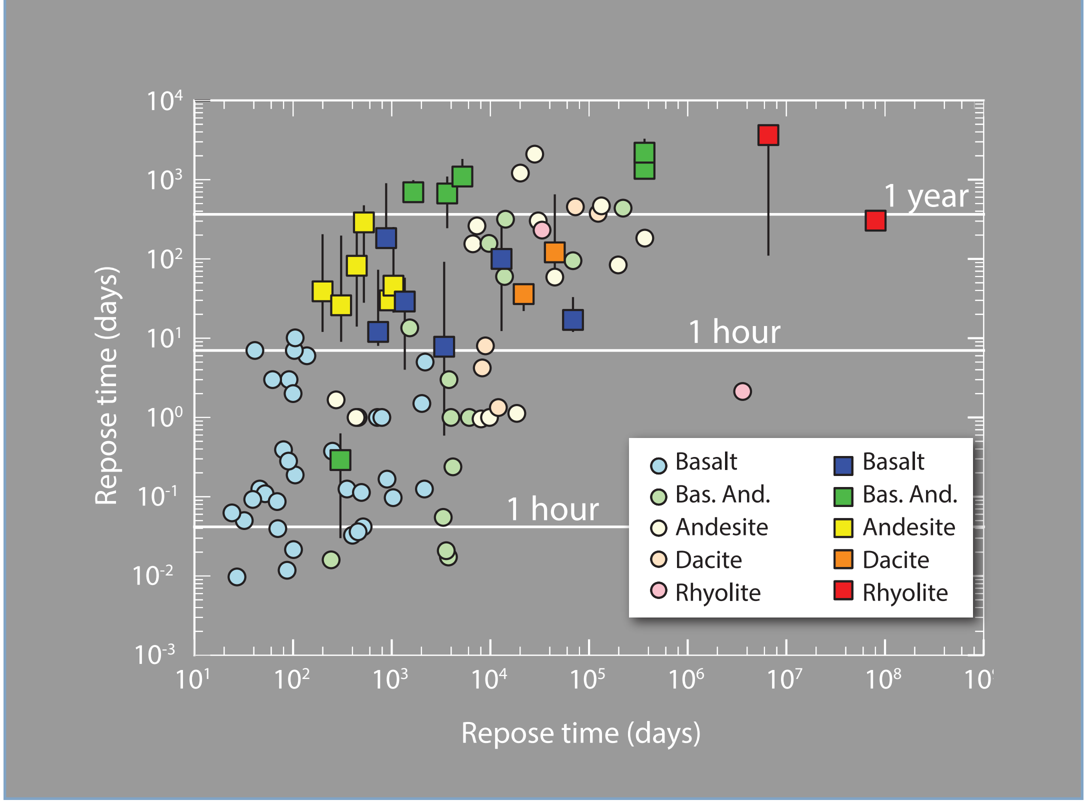


Figure 4. Run-up vs. repose. Modified after Passarelli and Brodsky (2012).

The crystal clocks described above have been adapted for the study of relatively short-timescale processes such as magma recharge; e.g., Lynn et al. (2018) demonstrated that zonation of Li in olivine may record magma recharge events that precede eruption by hours to days. Fe-Mg zonation in olivine (Lynn et al. 2017; Rasmussen et al. 2018b) can preserve evidence of multiple magma recharge events. When combined with the geophysical record of volcanic unrest, the petrologic record of magma recharge can provide a posteriori context that may aid the interpretation of future geophysical monitoring signals (Rasmussen et al. 2018b). Interdisciplinary studies that combine geophysical and geochemical records of volcanic unrest are vitally important for improving the accuracy of eruption forecasting. Additionally, we lack a general understanding of what controls the duration of run-up. Passarelli and Brodsky (2012) demonstrate that there is a broad correlation between run-up and repose (Fig. 4), yet the reason for this correlation remains puzzling.

Advancements in geospeedometers tuned to operate on even shorter timescales of seconds to hours have opened the door for research into syn-eruptive processes. Decompression-driven ascent of magma in volcanic conduits is accompanied by exsolution of volatile species such as water and carbon dioxide (Fig. 5A), and the imprint of this magma degassing is preserved as volatile concentration gradients in quenched silicate melt and crystals (Fig. 5C). Modeling of syn-eruptive volatile diffusion during magma decompression supports a relationship between decompression rate and eruptive style in basaltic systems, with rapidly decompressing magmas exhibiting higher mass eruption rates and vice versa (Chen et al. 2013; Lloyd et al. 2014; Ferguson et al. 2016; Barth et al. 2019; Newcombe et al. 2020). In rhyolitic systems, similar techniques have been used to study the onset and evolution of caldera-forming eruptions (Myers et al. 2016; Myers et al. 2018).

Another application of short-timescale diffusion chronometry is the use of MgO zonation in olivine-hosted melt inclusions to determine syneruptive cooling rates (Newcombe et al. 2014; Saper and Stolper 2020; Newcombe et al. 2020). When paired with the magma decompression chronometers described above, this technique can be used to constrain syneruptive pressure-temperature-time paths of mafic magmas; results of this approach suggest that rapidly-ascending gas-bearing magmas experience slower cooling during ascent and eruption than slowly-ascending magmas (Newcombe et al. 2020). Conduit models indicate that temperature changes of magma during syneruptive ascent exert a strong influence on ascent dynamics and eruptive style (Gonnermann and Manga 2007; La Spina et al. 2015). Future efforts to integrate the petrologic record of conduit conditions into fluid dynamical models of magma ascent and eruption will be required to advance our understanding of the controls on eruptive style.

Looking forward

This article has followed the journey of mantle-derived melts from their generation to eruption. Understanding this journey, and its importance for controlling the life cycles of volcanoes across the globe, is widely recognized as one of the grand challenges of volcano science (e.g., Volcanic Eruptions and Their Repose, Unrest, Precursors, and Timing "ERUPT" report of the National Academies, 2017). The GeoPRISMS community has studied every aspect of this journey, revealing a great deal about the nature of magma storage regions and the timescales of magma migration through the crust. The insights gleaned from GeoPRISMS work and the strong interdisciplinary community that we have forged will serve us well as we build new initiatives to answer the many remaining mysteries of volcanology. ■

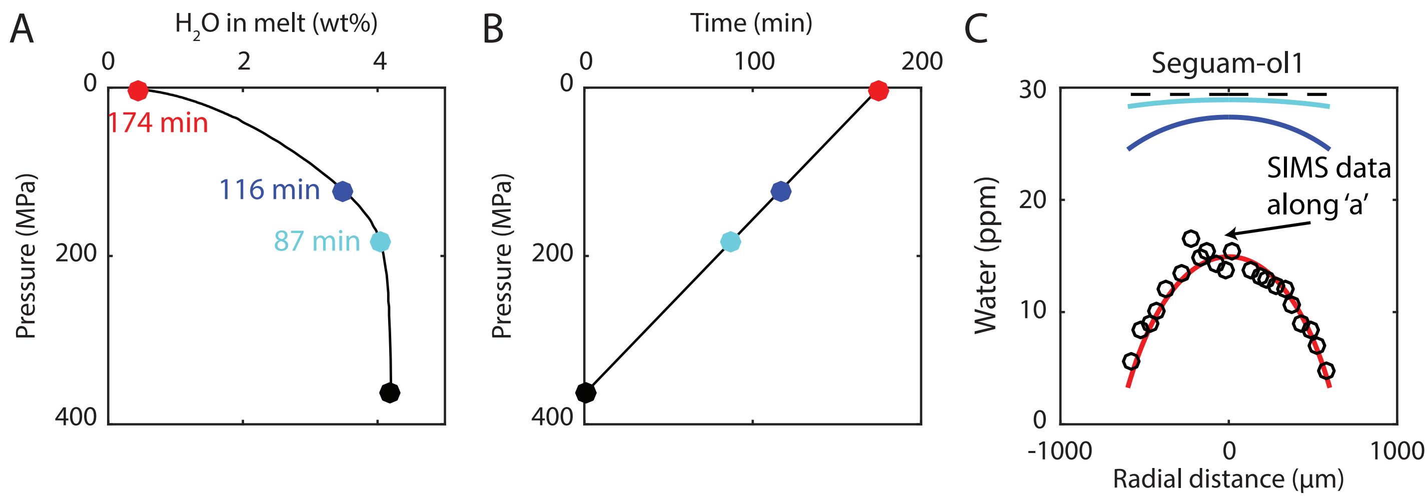


Figure 5. Application of the water-in-olivine magma decompression chronometer to an olivine phenocryst from Seguam volcano (Vona et al. 2011; Shea and Hammer 2013; La Spina et al. 2015). A) Basaltic magma containing ~4 wt% water degasses during magma ascent and decompression. Colored circles correspond to model snapshots plotted in C. B) The water-in-olivine assumes a constant magma decompression rate (dP/dt), which is varied in order to find the best fit to measured water concentration gradients in olivine phenocrysts. C) Water concentration data measured along the crystallographic 'a' direction of a Seguam olivine phenocryst (black circles) is well matched by the model curve (in red) with a constant decompression rate of 0.035 MPa/s. Blue curves represent snapshots of the modeled decompression history indicated by the colored circles in A and B.

References

Aiuppa A., A. Bertagnini, N. Métrich, R. Moretti, A. Di Muro, M. Liuzzo, G. Tamburello (2010). A model of degassing for Stromboli volcano. Earth Planet Sci Lett, 295, 1-2, 195-204

Aiuppa A., C. Federico, G. Giudice, S. Gurrieri (2005). Chemical mapping of a fumarolic field: La Fossa Crater, Vulcano Island (Aeolian Islands, Italy). Geophys Res Lett, 32, 13, doi:10.1029/2005gl023207

Aiuppa A., T.P. Fischer, T. Plank, P. Bani (2019). CO_2 flux emissions from the Earth's most actively degassing volcanoes, 2005–2015. Scientific Reports, 9, 1, 5442, doi:10.1038/s41598-019-41901-y

Albert H., F. Costa, A. Di Muro, J. Herrin, N. Métrich, E. Deloule (2019). Magma interactions, crystal mush formation, timescales, and unrest during caldera collapse and lateral eruption at ocean island basaltic volcanoes (Piton de la Fournaise, La Réunion). Earth Planet Sci Lett, 515, 187-199

Albert H., F. Costa, J. Martí (2016). Years to weeks of seismic unrest and magmatic intrusions precede monogenetic eruptions. Geology, 44, 3, 211-214

Anantrasirichai N., J. Biggs, F. Albino, D. Bull (2019). A deep learning approach to detecting volcano deformation from satellite imagery using synthetic datasets. Remote Sensing of Environment, 230, 111179

Andrys J., K.A. Kelley, E. Cottrell, M.L. Coombs (2018). Volatile contents of western Aleutian magmas and their relationship to slab thermal structure. In: AGU Fall Meeting Abstracts

Annen C., J. Blundy, R. Sparks (2006). The genesis of intermediate and silicic magmas in deep crustal hot zones. J Petrol, 47, 3, 505-539

Bachmann O., G. Bergantz (2008). The magma reservoirs that feed supereruptions. Elements, 4, 1, 17-21

Barth A., M.E. Newcombe, T. Plank, H. Gonnermann, S. Hajimirza, G.J. Soto, A. Saballos, E. Hauri (2019). Magma decompression rate correlates with explosivity at basaltic volcanoes - Constraints from water diffusion in olivine. J Volcanol Geotherm Res, 387

Bedrosian P.A, J.R. Peacock, E. Bowles-Martinez, A. Schultz, G.J. Hill (2018). Crustal inheritance and a top-down control on arc magmatism at Mount St Helens. Nat Geosci, 11, 11, 865-870

Bergantz G., J. Schleicher, A. Burgisser (2015). Open-system dynamics and mixing in magma mushes. Nat Geosci, 8, 10, 793-796

Blundy J., J. Mavrogenes B. Tattitch, S. Sparks, A. Gilmer (2015). Generation of porphyry copper deposits by gas–brine reaction in volcanic arcs. Nat Geosci, 8, 3, 235-240

Cai Y., M. Rioux, P.B. Kelemen, S.L. Goldstein, L. Bolge, A.R. Kylander-Clark (2015). Distinctly different parental magmas for calc-alkaline plutons and tholeiitic lavas in the central and eastern Aleutian arc. Earth Planet Sci Lett, 431, 119-126

Cameron C.E., S.G. Prejean, M.L. Coombs, K.L. Wallace, J.A. Power, D.C. Roman (2018). Alaska Volcano Observatory Alert and Forecasting Timeliness: 1989–2017. Frontiers in Earth Science, 6, 86, doi:10.3389/feart.2018.00086

Cashman K.V., R.S.J. Sparks, J.D. Blundy (2017). Vertically extensive and unstable magmatic systems: A unified view of igneous processes. Science, 355, 6331, eaag3055

Chaussard E., F. Amelung (2014). Regional controls on magma ascent and storage in volcanic arcs. Geochem Geophys, 15, 4, 1407-1418

Chen Y., A. Provost, P. Schiano, N. Cluzel (2013). Magma ascent rate and initial water concentration inferred from diffusive water loss from olivine-hosted melt inclusions. Contrib Mineral Petrol, 165, 3, 525-541, doi:10.1007/s00410-012-0821-x

Cooper K.M., A.J. Kent (2014). Rapid remobilization of magmatic crystals kept in cold storage. Nature, 506, 7489, 480-483

Couperthwaite F., A. Kent, P. Wallace, C. Till (2020). An initial evaluation of olivine diffusion timescales from monogenetic-style volcanoes in the Oregon High Cascades. In: AGU 2020 Fall Meeting

Costa F., D. Morgan (2011). Time constraints from chemical equilibration in magmatic crystals. Timescales of magmatic processes: from core to atmosphere. Wiley, Chichester, 125-159

Costa F., T. Shea, T. Ubide (2020). Diffusion chronometry and the timescales *of magmatic processes. Nat Rev Earth & Environment,1-14*

Crosbie K.J., G.A. Abers, M.E. Mann, H.A. Janiszewski, K.C. Creager, C.W. Ulberg, S.C. Moran (2019). Shear Velocity Structure From Ambient Noise and Teleseismic Surface Wave Tomography in the Cascades Around Mount St. Helens. J Geophys Res: Solid Earth, 124, 8, 8358-8375, doi:10.1029/2019jb017836

de Maisonneuve C.B., F. Costa, C. Huber, P. Vonlanthen, O. Bachmann, M.A. Dungan (2016). How do olivines record magmatic events? Insights from major and trace element zoning. Contrib Mineral Petrol, 171, 6, 56

de Moor J.M., A. Aiuppa, J. Pacheco, G. Avard, C. Kern, M. Liuzzo, M. Martínez, G. Giudice, T.P. Fischer (2016). Short-period volcanic gas precursors to phreatic eruptions: Insights from Poás Volcano, Costa Rica. Earth Planet Sci Lett, 442, 218-227, doi.org/10.1016/j.epsl.2016.02.056

DeBari S.M., A.R. Greene (2011). Vertical stratification of composition, density, and inferred magmatic processes in exposed arc crustal sections. In: Arc-continent collision. Springer, 121-144

DeGrandpre K., H. Le Mével (2019). Finite element, multiphysics eruption model: Okmok 2008 eruption characterized from InSAR, GPS, seismic, and petrologic constraints. AGU Fall Meeting 2019, abstract G31A-06

DeGrandpre K., T. Wang, Z. Lu, J.T. Freymueller (2017). Episodic inflation and complex surface deformation of Akutan volcano, Alaska revealed from GPS time-series. J Volcanol Geotherm Res, 347, 337-359

Degruyter W., C. Huber (2014). A model for eruption frequency of upper crustal silicic magma chambers. Earth Planet Sci Lett, 403, 117-130

Delph J.R., K.M. Ward, G. Zandt, M.N. Ducea, S.L. Beck (2017). Imaging a magma plumbing system from MASH zone to magma reservoir. Earth Planet Sci Lett, 457, 313-324

Ducea M.N., G.W. Bergantz, J.L. Crowley, J. Otamendi (2017). Ultrafast magmatic buildup and diversification to produce continental crust during subduction. Geology, 45, 3, 235-238

Ebmeier S., J. Biggs, T. Mather, F. Amelung (2013). On the lack of InSAR observations of magmatic deformation at Central American volcanoes. J Geophys Res: Solid Earth, 118, 5, 2571-2585

Ebmeier S., J. Biggs, M. Poland, M. Pritchard, S. Zoffoli, M. Furtney, K. Reath (2019). Satellite geodesy for volcano monitoring in the Sentinel-1 and SAR constellation era. In: IGARSS 2019-2019 IEEE International Geoscience and Remote Sensing Symposium. IEEE, 5465-5467

Fee D., M.M. Haney, R.S. Matoza, A.R. Van Eaton, P. Cervelli, D.J. Schneider, A.M. Iezzi (2017a). Volcanic tremor and plume height hysteresis from Pavlof Volcano, Alaska. Science, 355, 6320, 45-48, doi:10.1126/science.aah6108

Fee D., P. Izbekov, K. Kim, A. Yokoo, T. Lopez, F. Prata, R. Kazahaya, H. Nakamichi, M.M. Iguchi (2017b). Eruption mass estimation using infrasound waveform inversion and ash and gas measurements: Evaluation at Sakurajima Volcano, Japan. Earth Planet Sci Lett, 480, 42-52

Ferguson D.J., H.M. Gonnermann, P. Ruprecht, T. Plank, E.H. Hauri, B.F. Houghton, D.A. Swanson (2016). Magma decompression rates during explosive eruptions of Kīlauea volcano, Hawaii, recorded by melt embayments. Bull Volcanol, 78, 10, 71

Fischer T.P., S. Arellano, S. Carn, A. Aiuppa, B. Galle, P. Allard, T. Lopez, H. Shinohara, P. Kelly, C. Werner, C. Cardellini, G. Chiodini (2019). The emissions of CO_2 and other volatiles from the world's subaerial volcanoes. Scientific Reports, 9, 1, 18716, doi:10.1038/s41598-019-54682-1

Glasgow M.E., B. Schmandt, S.M. Hansen (2018). Upper crustal low-frequency seismicity at Mount St. Helens detected with a dense geophone array. J Volcanol Geotherm Res, 358, 329-341, doi.org/10.1016/j.jvolgeores.2018.06.006

Gonnermann H.M., M. Manga (2007). The fluid mechanics inside a volcano. Annual Review of Fluid Mechanics, 39, 1, 321-356, doi:10.1146/annurev.fluid.39.050905.110207

Gottsmann J., J. Biggs, R. Lloyd, Y. Biranhu, E. Lewi (2020). Ductility and compressibility accommodate high magma flux beneath a silicic continental rift caldera: Insights from Corbetti caldera (Ethiopia). Geochem Geophys, 21, 4

Grant E., K.M. Cooper, A. Kent, C.D. Deering, D. Gravley (2019). The earthquake flat and Rotoiti subsurface relationship (Taupo Volcanic Zone, New Zealand): A cryptic connection at depth? AGU Fall Meeting 2019, abstract V51F-0121

Hansen S., B. Schmandt, A. Levander, E. Kiser, J. Vidale, G. Abers, K. Creager (2016). Seismic evidence for a cold serpentinized mantle wedge beneath Mount St Helens. Nature Communi, 7, 1, 1-6

Hansen S.M., B. Schmandt (2015). Automated detection and location of microseismicity at Mount St. Helens with a large-N geophone array. Geophys Res Lett, 42, 18, 7390-7397, doi:10.1002/2015gl064848

Harmon L.J., G.A. Gualda, D. Gravley, C.D. Deering (2019) Oscillating Storage: The conditions and sequence of magma storage and eruption through the Protracted Whakamaru Supereruption, Taupo Volcanic Zone, New Zealand. AGUFM 2019:V14A-02

Hart L., N.L. Bennington, F. Lanza, S.W. Roecker, M.M. Haney, C.H. Thurber, K. Key (2018). High resolution imaging of the P-and S-wave velocity structure at Okmok Volcano, Alaska. In: AGU Fall Meeting Abstracts

Hartley M.E., J. Maclennan, M. Edmonds, T. Thordarson (2014). Reconstructing the deep CO_2 degassing behaviour of large basaltic fissure eruptions. Earth Planet Sci Lett, 393, 120-131, doi.org/10.1016/j.epsl.2014.02.031

Hildreth W., S. Moorbath (1988). Crustal contributions to arc magmatism in the Andes of central Chile. Contrib Mineral Petrol, 98, 4, 455-489

Huber C., M. Townsend, W. Degruyter, O. Bachmann (2019). Optimal depth of subvolcanic magma chamber growth controlled by volatiles and crust rheology. Nat Geosci, 12, 9, 762-768, doi:10.1038/s41561-019-0415-6

Husen A., R.R. Almeev, F. Holtz (2016). The effect of H_2O and pressure on multiple saturation and liquid lines of descent in basalt from the Shatsky Rise. J Petrol, 57, 2, 309-344

Janiszewski H.A., G.A. Abers, D.J. Shillington, J.A. Calkins (2013). Crustal structure along the Aleutian island arc: New insights from receiver functions constrained by active-source data. Geochem Geophys, 14, 8, 2977-2992, doi:10.1002/ggge.20211

Janiszewski H.A., L.S. Wagner, D.C. Roman (2020). Aseismic mid-crustal magma reservoir at Cleveland Volcano imaged through novel receiver function analyses. Scientific Reports, 10, 1, 1-9

Jiang C., B. Schmandt, J. Farrell, F.-C. Lin, K.M. Ward (2018). Seismically anisotropic magma reservoirs underlying silicic calderas. Geology, 46, 8, 727-730

Jicha B.R., O. Jagoutz (2015). Magma production rates for intraoceanic arcs. Elements, 11, 2, 105-111

Jicha B.R., D.W. Scholl, B.S. Singer, G.M. Yogodzinski, S.M. Kay (2006). Revised age of Aleutian Island Arc formation implies high rate of magma production. Geology, 34, 8, 661-664

Kahl M., S. Chakraborty, M. Pompilio, F. Costa (2015) Constraints on the nature and evolution of the magma plumbing system of Mt. Etna volcano (1991–2008) from a combined thermodynamic and kinetic modelling of the compositional record of minerals. J Petrol, 56, 10, 2025-2068

Kay S.M., B.R. Jicha, G.L. Citron, R.W. Kay, A.K. Tibbetts, T.A. Rivera (2019). The calc-alkaline Hidden Bay and Kagalaska plutons and the construction of the central Aleutian oceanic arc crust. J Petrol, 60, 2, 393-439

Kelemen P.B., C.E. Manning (2015). Reevaluating carbon fluxes in subduction zones, what goes down, mostly comes up. Proceedings of the National Academy of Sciences, 112, 30, E3997-E4006

Kim K., D. Fee, A. Yokoo, J.M. Lees (2015). Acoustic source inversion to estimate volume flux from volcanic explosions. Geophys Res Lett, 42, 13, 5243-5249

Kiser E., A. Levander, C. Zelt, B. Schmandt, S. Hansen (2019). Upper crustal structure and magmatism in Southwest Washington: Vp, Vs, and Vp/Vs results from the iMUSH active-source seismic experiment. J Geophys Res: Solid Earth, 124, 7, 7067-7080, doi:10.1029/2018jb016203

Kiser E., I. Palomeras, A. Levander, C. Zelt, S. Harder, B. Schmandt, S. Hansen, K. Creager, C. Ulberg (2016). Magma reservoirs from the upper crust to the Moho inferred from high-resolution Vp and Vs models beneath Mount St. Helens, Washington State, USA. Geology, 44, 6, 411-414

La Spina G., M. Burton, M. de' Michieli Vitturi (2015). Temperature evolution during magma ascent in basaltic effusive eruptions: A numerical application to Stromboli volcano. Earth Planet Sci Lett, 426, 89-100, doi.org/10.1016/j.epsl.2015.06.015

Laumonier M., F. Gaillard, D. Muir, J. Blundy, M. Unsworth (2017). Giant magmatic water reservoirs at mid-crustal depth inferred from electrical conductivity and the growth of the continental crust. Earth Planet Sci Lett, 457, 173-180

Le Voyer M., P.D. Asimow, J.L. Mosenfelder, Y. Guan, P.J. Wallace, P. Schiano, E.M. Stolper, J.M. Eiler (2014). Zonation of H_2O and F concentrations around melt inclusions in olivines. J Petrol, doi:10.1093/petrology/egu003

Lloyd A.S., P. Ruprecht, E.H. Hauri, W. Rose, H.M. Gonnermann, T. Plank (2014). NanoSIMS results from olivine-hosted melt embayments: Magma ascent rate during explosive basaltic eruptions. J Volcanol Geotherm Res, 283, 0, 1-18, doi.org/10.1016/j.jvolgeores.2014.06.002

Lynn K.J., M.O. Garcia, T. Shea, F. Costa, D.A. Swanson (2017). Timescales of mixing and storage for Keanakākoʻi Tephra magmas (1500–1820 C.E.), Kīlauea Volcano, Hawaiʻi. Contrib Mineral Petrol, 172, 9, 76. doi:10.1007/s00410-017-1395-4

Lynn K.J., T. Shea, M.O. Garcia, F. Costa, M.D. Norman (2018). Lithium diffusion in olivine records magmatic priming of explosive basaltic eruptions. Earth Planet Sci Lett 500, 127-135, doi.org/10.1016/j.epsl.2018.08.002

Malfante M., M. Dalla Mura, J.-P. Métaxian, J.I. Mars, O. Macedo, A. Inza (2018). Machine learning for volcano-seismic signals: Challenges and perspectives. IEEE Signal Processing Magazine, 35, 2, 20-30

Mann D., J. Freymueller (2003). Volcanic and tectonic deformation on Unimak Island in the Aleutian Arc, Alaska. J Geophys Res: Solid Earth, 108, B2

Marsh B.D. (2015). Magma chambers. In: The encyclopedia of volcanoes. Elsevier, 185-201

Martin V.M., D.J. Morgan, D.A. Jerram, M.J. Caddick, D.J. Prior, J.P. Davidson (2008) Bang! Month-scale eruption triggering at Santorini Volcano. Science, 321, 5893, 1178-1178, doi:10.1126/science.1159584

Miller D.J., N.L. Bennington, P. Bedrosian, M.M. Haney, K. Key, C.H. Thurber (2018). Constraining magma storage at Okmok Volcano via joint interpretation of the local velocity and resistivity structure. In: AGU Fall Meeting Abstracts

Mironov N., M. Portnyagin, R. Botcharnikov, A. Gurenko, K. Hoernle, F. Holtz (2015). Quantification of the CO_2 budget and H_2O–CO_2 systematics in subduction-zone magmas through the experimental hydration of melt inclusions in olivine at high H_2O pressure. Earth Planet Sci Lett, 425,1-11

Moore L.R., E. Gazel, R. Tuohy, A.S. Lloyd, R. Esposito, M. Steele-MacInnis, E.H. Hauri, P.J. Wallace, T. Plank, R.J. Bodnar (2015). Bubbles matter: An assessment of the contribution of vapor bubbles to melt inclusion volatile budgets. Amer Miner, 100, 4, 806-823, doi:10.2138/am-2015-5036

Moran S.C., C. Newhall, D.C. Roman (2011). Failed magmatic eruptions: late-stage cessation of magma ascent. Bull Volcanol, 73, 2, 115-122

Morris R.A., S.M. DeBari, C. Busby, S. Medynski, B.R. Jicha (2019). Building arc crust: Plutonic to volcanic connections in an extensional oceanic arc, the Southern Alisitos Arc, Baja California. J Petrol 60, 6, 1195-1228, doi:10.1093/petrology/egz029

Mutch E.J., J. Maclennan, O. Shorttle, M. Edmonds, J.F. Rudge (2019). Rapid transcrustal magma movement under Iceland. Nat Geosci, 12, 7, 569-574

Myers M.L., P.J. Wallace, C.J. Wilson, J.M. Watkins, Y. Liu (2018). Ascent rates of rhyolitic magma at the onset of three caldera-forming eruptions. Min Soc Am, 103, 6, 952-965, doi.org/10.2138/am-2018-6225

Myers M.L., P.J. Wallace, C.J.N. Wilson, B.K. Morter, E.J. Swallow (2016). Prolonged ascent and episodic venting of discrete magma batches at the onset of the Huckleberry Ridge supereruption, Yellowstone. Earth Planet Sci Lett, 451, 285-297, doi.org/10.1016/j.epsl.2016.07.023

Neave D.A., K.D. Putirka (2017). A new clinopyroxene-liquid barometer, and implications for magma storage pressures under Icelandic rift zones. Amer Miner, 102, 4, 777-794

Newcombe M.E., A. Fabbrizio, Y. Zhang, C. Ma, M. Le Voyer, Y. Guan, J.M. Eiler, A.E. Saal, E.M. Stolper (2014). Chemical zonation in olivine-hosted melt inclusions. Contrib Mineral Petrol, 168, 1, 1-26, doi:10.1007/s00410-014-1030-6

Newcombe M.E., T. Plank, P.D. Asimow, A. Barth, E. Hauri (2020). Water-in-olivine magma ascent chronometry: Every crystal is a clock. J Volcanol Geotherm Res

Newcombe M.E., T. Plank, Y. Zhang, M. Holycross, A. Barth, A.S. Lloyd, D.J. Ferguson, E. Hauri (2020). Magma Pressure-Temperature-time paths during mafic explosive eruptions. Frontiers in Earth Science, doi.org/10.3389/feart.2020.531911

Newhall C.G., F. Costa, A. Ratdomopurbo, D.Y. Venezky, C. Widiwijayanti, N.T.Z. Win, K. Tan, E. Fajiculay (2017). WOVOdat – An online, growing library of worldwide volcanic unrest. J Volcanol Geotherm Res, 345, 184-199, doi.org/10.1016/j.jvolgeores.2017.08.003

Nichols M.L., S.D. Malone, S.C. Moran, W.A. Thelen, J.E. Vidale (2011). Deep long-period earthquakes beneath Washington and Oregon volcanoes. J Volcanol Geotherm Res, 200 3, 116-128, doi.org/10.1016/j.jvolgeores.2010.12.005

Passarelli L., E.E. Brodsky (2012). The correlation between run-up and repose times of volcanic eruptions. Geophys J Int, 188, 3, 1025-1045

Pamucku et al., 2015

Pitcher B.W., A.J. Kent (2019). Statistics and segmentation: Using Big Data to assess Cascades Arc compositional variability. Geochim Cosmochim Acta, 265, 443-467

Poland M.P., A. Miklius, A. Jeff Sutton, C.R. Thornber (2012). A mantle-driven surge in magma supply to Kīlauea Volcano during 2003–2007. Nat Geosci, 5, 4, 295-300. doi:10.1038/ngeo1426

Power J., S. Stihler, R. White, S. Moran (2004). Observations of deep long-period (DLP) seismic events beneath Aleutian arc volcanoes; 1989–2002. J Volcanol Geotherm Res, 138, 3-4, 243-266

Power J.A., et al. (2020). Goals and development of the Alaska Volcano Observatory Seismic Network and application to forecasting and detecting volcanic eruptions. Seismol Res Lett, 91, 2A, 647-659, doi:10.1785/0220190216

Pritchard M., J. Biggs, C. Wauthier, E. Sansosti, D.W. Arnold, F. Delgado, S. Ebmeier, S. Henderson, K. Stephens, C. Cooper (2018). Towards coordinated regional multi-satellite InSAR volcano observations: results from the Latin America pilot project. J Appl Volcanol, 7, 1, 5

Putirka K.D. (2017). Down the crater: where magmas are stored and why they erupt. Elements, 13, 1, 11-16

Rasmussen D.J., T.A. Plank, D.C. Roman (2019). Magmatic water content controls magma storage depth. AGU Fall Meeting 2019, abstract V21A-06

Rasmussen D.J., T.A. Plank, D.C. Roman, E. Hauri, H.A. Janiszewski, E. Lev, K.P. Nicolaysen, P.E. Izbekov (2018a). How Slab Depth is Reflected in Aleutian Arc Magmas. In: AGU Fall Meeting Abstracts

Rasmussen D.J., T.A. Plank, D.C. Roman, J.A. Power, R.J. Bodnar, E.H. Hauri (2018b). When does eruption run-up begin? Multidisciplinary insight from the 1999 eruption of Shishaldin volcano. Earth Planet Sci Lett, 486, 1-14

Rasmussen D.J., T.A. Plank, P.J. Wallace, M.E. Newcombe, J.B. Lowenstern (2020). Vapor bubble growth in olivine-hosted melt inclusions. Amer Miner

Reath K., M. Pritchard, J. Biggs, B. Andrews, S. Ebmeier, M. Bagnardi, T. Girona, P. Lundgren, T. Lopez, M. Poland (2019). Using conceptual models to relate multi-parameter satellite data to sub-surface volcanic processes in Latin America. Geochem Geophys

Rocco N., A.J. Kent, K.M. Cooper, C.D. Deering, D. Gravley (2019). Investigating Crustal and Mantle Contributions using Pb and Sr Isotopes in Okataina and Taupo Volcanic Centers, Taupo Volcanic Zone, New Zealand. AGU Fall Meeting 2019. abstract V51H-0137

Roman D., J. Neuberg, R. Luckett (2006). Assessing the likelihood of volcanic eruption through analysis of volcanotectonic earthquake fault–plane solutions. Earth Planet Sci Lett, 248, 1-2, 244-252

Roman D.C., K.V. Cashman (2018). Top-down precursory volcanic seismicity: Implications for 'stealth'magma ascent and long-term eruption forecasting. Frontiers in Earth Science, 6, 124

Roman D.C., M.D. Gardine (2013). Seismological evidence for long-term and rapidly accelerating magma pressurization preceding the 2009 eruption of Redoubt Volcano, Alaska. Earth Planet Sci Lett, 371, 226-234

Rosen J. (2016). Crystal clocks. Science, 354, 6314, 822-825, DOI: 10.1126/science.354.6314.822

Roult G., A. Peltier, B. Taisne, T. Staudacher, V. Ferrazzini, A. Di Muro (2012). A new comprehensive classification of the Piton de la Fournaise activity spanning the 1985–2010 period. Search and analysis of short-term precursors from a broad-band seismological station. J Volcanol Geotherm Res, 241, 78-104

Rudnick R.L., S.L. Goldstein (1990). The Pb isotopic compositions of lower crustal xenoliths and the evolution of lower crustal Pb. Earth Planet Sci Lett, 98, 2, 192-207

Ruprecht P., T. Plank (2013). Feeding andesitic eruptions with a high-speed connection from the mantle. Nature, 500, 7460, 68-72

Ruscitto D., P. Wallace, E. Johnson, A. Kent, I. Bindeman (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 Planet Sci Lett, 298, 1-2, 153-161

Ruth D.C., F. Costa, C.B. de Maisonneuve, L. Franco, J.A. Cortés, E.S. Calder (2018). Crystal and melt inclusion timescales reveal the evolution of magma migration before eruption. Nat Communi, 9, 1, 1-9

Salas P.A., O.M. Rabbia, L.B. Hernández, P. Ruprecht (2017). Mafic monogenetic vents at the Descabezado Grande volcanic field (35.5 S–70.8 W): The northernmost evidence of regional primitive volcanism in the Southern Volcanic Zone of Chile. Int J Sci, 106, 3, 1107-1121

Saper L., E. Stolper (2020). Controlled cooling-rate experiments on olivine-hosted melt inclusions: chemical diffusion and quantification of eruptive cooling-rates on Hawaii and Mars. Geochem Geophys, 21, 2, e2019GC008772, doi:10.1029/2019GC008772

Saunders K., B. Buse, M.R. Kilburn, S. Kearns, J. Blundy (2014). Nanoscale characterisation of crystal zoning. Chem Geol, 364, 0, 20-32, doi.org/10.1016/j.chemgeo.2013.11.019

Schlieder T., K.M. Cooper, A. Kent, C.D. Deering, D. Gravley (2019). Understanding the thermal and chemical state of a silicic magmatic system prior to caldera-forming eruptions: Taupo Volcanic Center, New Zealand. AGU Fall Meeting 2019, abstract V51F-0125

Shea T., J.E. Hammer (2013). Kinetics of cooling- and decompression-induced crystallization in hydrous mafic-intermediate magmas. J Volcanol Geotherm Res, 260, 127-145, doi.org/10.1016/j.jvolgeores.2013.04.018

Shillington D.J., H.J. Van Avendonk, M.D. Behn, P.B. Kelemen, O. Jagoutz (2013). Constraints on the composition of the Aleutian arc lower crust from VP/VS. Geophys Res Lett, 40, 11, 2579-2584

Shillington D.J., H.J.A. Van Avendonk, W.S. Holbrook, P.B. Kelemen, M.J. Hornbach (2004). Composition and structure of the central Aleutian island arc from arc-parallel wide-angle seismic data. Geochem Geophys, 5, 10, doi:10.1029/2004gc000715

Shinohara H. (2005). A new technique to estimate volcanic gas composition: plume measurements with a portable multi-sensor system. J Volcanol Geotherm Res, 143, 4, 319-333, doi.org/10.1016/j.jvolgeores.2004.12.004

Sides I., M. Edmonds, J. Maclennan, D. Swanson, B. Houghton (2014). Eruption style at Kīlauea Volcano in Hawai 'i linked to primary melt composition. Nat Geosci, 7, 6, 464-469

Stephens K., C. Wauthier (2018). Satellite geodesy captures offset magma supply associated with lava lake appearance at Masaya volcano, Nicaragua. Geophys Res Lett, 45, 6, 2669-2678

Sun J., C. Wauthier, K. Stephens, M. Gervais, G. Cervone, P.C. La Femina, M. Higgins (2019). Deep learning application on volcanic deformation detection and blind source separation in InSAR Data. AGU Fall Meeting 2019, G13C-0556

Syracuse E.M., G.A. Abers (2006). Global compilation of variations in slab depth beneath arc volcanoes and implications. Geochem Geophys, 7, 5

Till C.B., A.J.R. Kent, G.A. Abers, H.A. Janiszewski, J.B. Gaherty, B.W. Pitcher (2019). The causes of spatiotemporal variations in erupted fluxes and compositions along a volcanic arc. Nat Communi, 10, 1, 1350. doi:10.1038/s41467-019-09113-0

Turner S.J., C.H. Langmuir, R.F. Katz, M.A. Dungan, S. Escrig (2016). Parental arc magma compositions dominantly controlled by mantle-wedge thermal structure. Nat Geosci, 9, 10, 772-776

Ubide T., C.A. McKenna, D.M. Chew, B.S. Kamber (2015). High-resolution LA-ICP-MS trace element mapping of igneous minerals: In search of magma histories. Chem Geol, 409, 157-168

Ulberg C.W., K.C. Creager, S.C. Moran, G.A. Abers, W.A. Thelen, A. Levander, E. Kiser, B. Schmandt, S.M. Hansen, R.S. Crosson (2020). Local source Vp and Vs tomography in the Mount St. Helens region with the iMUSH broadband array. Geochem Geophys

van Keken P.E., B.R. Hacker, E.M. Syracuse, G.A. Abers (2011). Subduction factory: 4. Depth-dependent flux of H2O from subducting slabs worldwide. J Geophys Res: Solid Earth, 116, B1

Vogt K., T.V. Gerya, A. Castro (2012). Crustal growth at active continental margins: numerical modeling. Phys Earth Planet Inter, 192, 1-20

Vona A., C. Romano, D.B. Dingwell, D. Giordano (2011). The rheology of crystal-bearing basaltic magmas from Stromboli and Etna. Geochim Cosmochim Acta, 75, 11, 3214-3236, doi.org/10.1016/j.gca.2011.03.031

Walker Jr B.A., G.W. Bergantz, J.E. Otamendi, M.N. Ducea, E.A. Cristofolini (2015). A MASH zone revealed: The mafic complex of the Sierra Valle Fértil. J Petrol, 56, 9, 1863-1896

Wallace P.J., V.S. Kamenetsky, P. Cervantes (2015). Melt inclusion CO2 contents, pressures of olivine crystallization, and the problem of shrinkage bubbles. Amer Miner, 100, 4, 787-794, doi:10.2138/am-2015-5029

Walowski K., P. Wallace, K. Cashman, J. Marks, M. Clynne, P. Ruprecht (2019). Understanding melt evolution and eruption dynamics of the 1666 CE eruption of Cinder Cone, Lassen Volcanic National Park, California: Insights from olivine-hosted melt inclusions. J Volcanol Geotherm Res, 387, 106665

Werner C., C. Kern, D. Coppola, J.J. Lyons, P.J. Kelly, K.L. Wallace, D.J. Schneider, R.L. Wessels (2017). Magmatic degassing, lava dome extrusion, and explosions from Mount Cleveland volcano, Alaska, 2011–2015: Insight into the continuous nature of volcanic activity over multi-year timescales. J Volcanol Geotherm Res, 337, 98-110

Werner C., D.J. Rasmussen, T. Plank, P.J. Kelly, C. Kern, T. Lopez, J. Gliss, J.A. Power, D.C. Roman, P. Izbekov, J. Lyons (2020). Linking Subsurface to Surface using Gas Emission and Melt Inclusion data at Mount Cleveland volcano, Alaska. Geochem Geophys, 21, 7, e2019GC008882, doi:10.1029/2019gc008882

Werner C.A., M.P. Doukas, P.J. Kelly (2011). Gas emissions from failed and actual eruptions from Cook Inlet Volcanoes, Alaska, 1989–2006. Bull Volcanol, 73, 2, 155-173, doi:10.1007/s00445-011-0453-4

Wilkinson J.J. (2013). Triggers for the formation of porphyry ore deposits in magmatic arcs. Nat Geosci, 6, 11, 917-925, doi:10.1038/ngeo1940

Wnuk K., C. Wauthier (2017). Surface deformation induced by magmatic processes at Pacaya Volcano, Guatemala revealed by InSAR. J Volcanol Geotherm Res, 344, 197-211, doi.org/10.1016/j.jvolgeores.2017.06.024

Yogodzinski G., P. Kelemen (2007). Trace elements in clinopyroxenes from Aleutian xenoliths: Implications for primitive subduction magmatism in an island arc. Earth Planet Sci Lett, 256, 3-4, 617-632

Zajacz Z., J.H. Seo, P.A. Candela, P.M. Piccoli, C.A. Heinrich, M. Guillong (2010). Alkali metals control the release of gold from volatile-rich magmas. Earth Planet Sci Lett, 297, 1-2, 50-56

Zellmer G.F., M. Pistone, Y. Iizuka, B.J. Andrews, A. Gómez-Tuena, S.M. Straub, E. Cottrell (2016). Petrogenesis of antecryst-bearing arc basalts from the Trans-Mexican Volcanic Belt: Insights into along-arc variations in magma-mush ponding depths, H_2O contents, and surface heat flux. Amer Miner, 101, 11, 2405-2422

Zimmer M.M., T. Plank, E.H. Hauri, G.M. Yogodzinski, P. Stelling J. Larsen, B. Singer, B. Jicha, C. Mandeville, C.J. Nye (2010). The Role of Water in Generating the Calc-alkaline Trend: New Volatile Data for Aleutian Magmas and a New Tholeiitic Index. J Petrol, 51, 12, 2411-2444, doi:10.1093/petrology/egq062