Editorial

Evolution, transfer and release of magmas and volcanic gases: An introduction

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\textbf{A B S T R A C T}

In this introduction, recent progress in the study of the evolution, transfer and release of magmas and volcanic gases is briefly reviewed, based on discussions at the MAG2007 international conference held in Taipei, Taiwan, in April 2007. The meeting pooled the diverse expertise of igneous and volcanic gas geochemists. This special issue, which presents six case studies covering a range of topics from variations in mantle source compositions to the nature of volcanic degassing, reflects that diversity.

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1. Introduction

The contributions in this book are based on the productive and controversial conference on “Evolution, transfer and release of magmas and volcanic gases” (MAG2007, Zellmer et al., 2007). MAG2007 was the first international workshop devoted to bringing together igneous and gas geochemists working on volcanology-related topics. It was held at the Institute of Earth Sciences, Academia Sinica, and at Taiwan’s East Coast, from 22 to 27 April 2007, and hosted an international group of some 45 researchers of volcanology and igneous and gas geochemistry.

The conference was organized around a thematic set of keynote presentations by leading researchers. Igneous processes discussed included rates of magma generation, evolution and degassing, insights on magma dynamics from Mount St. Helens, processes of incremental growth of magma reservoirs, and the mechanisms and timescales of crustal assimilation. Volcanic gas geochemistry contributions focused on sources of volcanic gas emissions, degassing fluxes from subduction zones, satellite based monitoring of volcanic emissions, and continuous degassing from open conduits. Moderated in-depth discussions of these and related topics provided many new insights in the relationship between information gained from igneous and gas geochemical studies, some of which are presented in this special issue.

2. A review of recent research efforts

2.1. Igneous studies

Uranium series isotope studies provide an invaluable tool for gaining insights into the processes and timescales of magma generation and evolution. Disequilibria in the uranium series decay chains can be introduced through geological processes such as melting and degassing (e.g., Berlo et al., 2006; Sims and Hart, 2006). The decay of such disequilibria may then be used to date these processes. Case studies that employ such techniques include the timescales of melt generation and migration at ocean ridges (e.g., Sims et al., 2002), and the rates of differentiation and magma recharge in crustal reservoirs (e.g., Dosseto et al., 2008).

A new method to constrain magmatic processes leading to eruptions of intermediate arc volcanoes is the study of plagioclase-hosted melt inclusions (Blundy and Cashman, 2005). These give direct evidence for degassing-induced crystallization during decompression in a rising magma column, consistent with chemical variations in the host minerals (Blundy and Cashman, 2001; Berlo et al., 2007). The latent heat of crystallization may increase magma temperatures by up to 100 °C, providing an alternative explanation for many disequilibrium textures observed in intermediate arc volcanic products that are frequently attributed to heating by influx of hotter, more mafic lavas (Blundy et al., 2006). Data on variations in the Li content of melt inclusions in recent Mount St. Helens dacites indicate the condensation of a Li-rich brine at depth (Kent et al., 2007).

Recent advances in the understanding of magma differentiation and shallow magma storage have resulted from modeling of incremental growth of magma reservoirs. The controlling parameters are the geothermal gradient, depth of intrusion, intruded magma volume, fertility of the magma, and the emplacement geometry and rate (e.g., Pettford and Gallagher, 2001; Annen and Sparks, 2002; Annen et al., 2006a). Although models of over-accretion, under-accretion and random accretion result in different degrees and timescales of crustal melting, the partial/residual melt ratio is governed by emplacement rate (Annen et al., in press). These principles can be applied to melt generation and evolution in deep crustal hot zones, as well as shallow magma chambers of different sizes, where accretion rates of the order...
of $10^{-3}$ to $10^{-2}$ m yr$^{-1}$ are inferred by combining thermal models with a variety of external constraints (Annen et al., 2006b; Annen et al., 2007).

Frequently, there is evidence for crustal assimilation in erupted volcanic products. Over prolonged periods of volcanic activity, high-precision Pb isotope data allow tracking that assimilation. For example, the East Greenland flood basalts provide evidence for increasing crustal contamination with decreasing magma supply rate over millions of years (Peate et al., 2008). Olivine hosted melt inclusions have been used to quantify assimilation during early stages of crystallization of flood basalts from Yemen (e.g., Kent et al., 2002). Faster assimilation rates over shorter time periods can be assessed in younger magmatic systems (which are also suitable for uranium series dating). In the Ice Springs flow of SW Utah, dissolution of crustal xenoliths appears to take months to years and may be responsible for the entire observed geochemical variation within the flow.

2.2. Volcanic gas studies

The sources, variations and implications of volcanic gas emissions may be investigated through a variety of gas sampling and monitoring methods. At volcanic arcs, systematic variations in gas species and isotopic compositions with tectonic setting provide insights into the relative contributions of volatiles from crust, mantle and subducting slab (e.g., Fischer et al., 1997; 2002a; Hilton et al., 2002). Monitoring changes in volcanic activity requires high-resolution time-series data (cf. Fischer et al., 2002b). Integration of gas analyses with petrological studies, particularly melt inclusion and ash leachate geochemical work, allows the detailed study of volcanic processes (de Moor et al., 2005).

While in principle the budget of gas exsolution from cooling and decompressing magmas and of interactions with the crust can be resolved (e.g., Mather et al., 2006), sparse sampling density makes it difficult to infer global-scale degassing fluxes from local studies, particularly when attempting to constrain trace gas emissions. However, recent developments of portable ground-based and remote sensing instruments for the measurements of reactive volcanicogenic trace gases is currently improving our knowledge of their budgets (e.g., McGonigle et al., 2002; Aiuppa et al., 2007; Bagnato et al., 2007)

Evaluation of global scale gas emissions is assisted by advances in satellite based monitoring of volcanic emissions. A variety of space-based instrumentation in principle allows the detection of SO$_2$, BrO, HCl and aerosols, although in practice SO$_2$ release is the only species which – to date – can be well quantified. Recent improvements in the resolution of space-based monitoring enables the tracking of evolving volcanic gas plumes in the atmosphere during passive degassing (e.g., Prata et al., 2007). Detection of passive, i.e. non-eruptive degassing from space is a significant step forward towards continuous monitoring of volcanoes. Satellite based monitoring also enables the quantification of degassing fluxes of remote volcanoes, and therefore helps to constrain the global SO$_2$ flux into the atmosphere (e.g., Carn et al., 2007b). Finally, anthropogenically produced SO$_2$ may also be detected (e.g., Carn et al., 2007a).

Non-eruptive continuous degassing, as for example observed in Etna, Stromboli, Masaya, Sakurajima and Miyakojima, amounts to more than half of the global degassing budget from subaerial volcanoes. It is therefore important to understand the mechanisms of passive degassing. Gas compositions indicate low pressure degassing, and the volume of magma to supply this gas flux is significantly larger than the erupted volume. Hence, magmatic convection in the conduit is required, with volatile rich magma rising and degassed magma sinking due to its higher density (e.g., Kuzahayata et al., 1994; Stevenson and Blake, 1998).

Magma degassing rates also provide key insights into the processes operating in the subvolcanic magmatic system (e.g., Gauthier et al., 2000; Le Cloarec and Gauthier, 2003).

3. Contributions of this special issue

This special issue presents six case studies governing a range of topics from variations in mantle source compositions to the nature of volcanic degassing.

In a geochemical and isotopic study of basaltic glasses from the Central Lau Basin, SW Pacific, Tian et al. (2008–this issue) show that the mantle source composition beneath the spreading centres is affected by contributions from the subducted slab, which decrease with distance from the arc. Slab contributions are dominated by hydrous fluids that influence the degree of mantle melting in this area.

Moving to shallower processes close to the crust–seawater interface, Palinkaš et al. (2008–this issue) employ volcanic facies analysis of a lava-flow complex exposed in NW Croatia to provide evidence for advanced rifting in a subsiding basin during Triassic times, preceeding the opening of the Dinaric Tethys ocean. A variety of facies are recognised and linked to lava extrusion above, at, and beneath the seawater/sediment interface.

Field occurrences, petrography and mineral and rock geochemistry are used by Lai et al. (2008–this issue) to investigate mingled magmas in the Neogene Coastal Range of Eastern Taiwan, exposed by arc-continent collision. They identify three components: mafic magma and felsic magma that may have been derived from the same source, and sediments. Mingling occurred prior to solidification, but at or near the surface, not in a magma chamber.

The study by Rowe et al. (2008–this issue) on Li and Cu variations in Mount St. Helens amphibole crystals erupted between 2004 and 2005 provides the transition to the evolution of the vapor phase prior to eruption. Temporal compositional variations are explained through a diffusion-crystallization multi-stage model, in which Li and Cu are partitioned into a fluid phase during ascent and crystallization of the magma. Low Li and Cu in early erupted amphiboles indicate equilibration with a Li–Cu depleted melt, and suggest that crystals in the early dacite may have been derived from the previous eruptive episode of 1980–1986.

Changing compositions of volcanic-hydrothermal gases and He isotopes from fumaroles in the Tatun Volcano Group, northern Taiwan, linked to increased seismic activity and a rise in fumarole temperature, are described by Lee et al. (2008–this issue). The authors consider new magma supply and recent opening of upper crustal fractures, and favour the latter interpretation to explain their observations.

Finally, the magmatically and tectonically active Tatun Volcano Group was also the subject of a volcanic emission study by Witt et al. (2008–this issue), which combined Multi-GAS and Giggenbach flask techniques for the analysis of common gas species with gaseous elemental mercury measurements (GEM) using a portable mercury spectrometer. Besides identifying elevated GEM levels in the Tatun fumarole plume, this work provides important insights into comparability issues between data derived by Multi-GAS and Giggenbach flask methods.

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