American Mineralogist, Volume 95, pages 671–672, 2010

Book Review

MINERALS, INCLUSIONS AND VOLCANIC PROCESSES, Keith D. Putirka and Frank J. Tepley, Editors. (2008) Reviews in Mineralogy and Geochemistry, vol. 69, 674 pp. ISBN: 978-0-939950-83-6. $40 (http://www.minsocam.org/MSA/Rim/Rim69.html)

Igneous petrology is moving toward more and more powerful techniques applied at smaller and smaller length scales. Minerals and their inclusions record a wealth of information about the compositional, thermal, volatile, and pressure conditions experienced by magmas between their source regions and the surface. A host of different techniques can now provide us with data about pre-eruptive magma storage, mechanisms and rates of magma ascent, the nature and effects of volatile degassing, magma mingling and hybridization, and the time scales over which these processes occur. This RiMG volume is an impressive compilation of papers that review the fundamental tools of the igneous petrologist, from textural studies to radioactive disequilibria and diffusion modeling. The text formed the basis for a MSA Short Course, and the MSA website (http://www.minsocam.org/MSA/RIM/Rim69.html) provides links to the presentation materials from the course, as well as Excel spreadsheets that accompany several of the chapters, addressing topics such as thermobarometry and volatile solubility. Additional resources are available online through the NAGT "On The Cutting Edge" project, including tutorials on analytical techniques and relevant teaching exercises (http://serc.carleton.edu/NAGTWorskshops/petrology).

The volume covers four key aspects of petrology: (1) kinetics and thermobarometry, (2) volatiles, fluid inclusions and melt inclusions, (3) stable and radioactive isotope systems, and (4) textural studies.

The volume starts with the kinetics of crystallization (Julia Hammer), outlined in the context of experiments on cooling of basaltic magma and decompression of felsic magmas. The chapter also describes methods for quantifying experimental textures. The next three chapters describe thermobarometry for volcanic (Keith Putirka) and granitic systems (Lawford Anderson and others) as well as fluid inclusions (Thor Hansteen and Andreas Klügel). Putirka concentrates on mineral-melt and mineral-mineral thermometers, and includes sections on testing for equilibrium, error treatment, and some applications to natural systems. Anderson and others describe thermometers based on trace-element abundances (e.g., Ti in quartz) as well as minor or accessory phases, including zircon, sphene, and rutile. Hansteen and Klügel focus on methods for fluid inclusion analysis and demonstrate the use of inclusion density distributions to infer thermobarometric and petrologic information.

The next major section of the volume deals with melt inclusions, volatiles, and magma ascent rates. Jon Blundy and Kathy Cashman give a comprehensive review of methods to quantify pre-eruptive magmatic variables and include an assessment of the effectiveness of each method. They demonstrate the insight that can be obtained by integrating petrological and volcano monitoring data, focusing on magma degassing and crystallization at Mount St Helens and other volcanoes. The following chapter (Malcolm Rutherford) analyses the variations in mass eruption rate that characterize many arc volcanoes and reviews the techniques used to estimate magma ascent rates, including textural analysis, hornblende breakdown, and xenolith-melt reaction. The next three chapters comprise a comprehensive review and formula for analysis and interpretation of melt inclusions, which will be invaluable for anyone using or intending to use these techniques. Adam Kent addresses melt inclusions in broadly basaltic compositions. He describes methods of sample preparation, common analytical techniques, and issues relating to post-entrapment modification. He also discusses concerns over the compositional diversity of inclusions from individual samples, and summarizes some applications to mafic rocks. This chapter is followed by a review (Gordon Moore) of volatile solubility in natural melts as a function of pressure, temperature and melt composition, focusing on pure H_2O, pure CO_2, and mixed H_2O-CO_2 fluids. Moore also reviews solubility models, which are essential for interpretation of volatile data from melt inclusions and matrix glasses. Finally, Nicole Métrich and Paul Wallace examine the reconstruction of volatile degassing paths from melt inclusion data, focusing on olivine-hosted basaltic inclusions. They cover shallow-level magmatic processes including gas fluxing and magma recharge, and they discuss primary magmatic volatile contents.

Stable and radioactive isotopic systems and time scales are incorporated in the next four chapters, including both single-crystal and intracrystalline studies. Frank Ramos and Frank Tepley give a technical review of analytical techniques for different isotopic systems and describe the application of each technique to volcanic processes. They also describe Sr and Pb isotope analysis in single crystals. Ilya Bindeman discusses single-crystal, oxygen-isotope studies, including both theory and a review of oxygen-isotope disequilibria case studies as well as their implications for understanding magma genesis. U-series analysis is covered by Kari Cooper and Mary Reid, with a comprehensive review of sample preparation and analytical techniques and methods for age calculation. They discuss the interpretation of age data from bulk minerals and crystal populations with several recent examples, and highlight the need to integrate age information with other petrological data. In the following chapter, Fidel Costa

0003-004X/10/0004–671$05.00/DOI: 10.2138/am.2010.552

and others provide an excellent "recipe" for obtaining magmatic time scales from diffusion profiles in zoned crystals, including a summary of the theory and mathematical treatment of diffusion profiles. They consider various initial boundary conditions and also discuss potential problems of diffusion modeling. This chapter will be essential reading for researchers wishing to use diffusion modeling to obtain time scale information.

The final section of the volume looks at textural analysis of both individual crystals and crystal populations. Martin Streck reviews mineral zoning that includes a discussion of specific textures commonly observed in different mineral phases and summarizes the evidence for open-system magma chamber processes. Pietro Armienti describes quantitative textural analysis using crystal-size distributions and includes theoretical perspectives and some recent examples. Finally, Olivier Bachmann and George Bergantz take a macroscale look at the types of zoning observed in erupted ignimbrites and the mechanisms for producing them, and they include comments on the potential for homogenization of large-volume silicic systems.

This compilation of papers comprises an exceptional review volume that will not only be an essential reference for igneous petrologists but will also stimulate future collaborative studies integrating different techniques.

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