American Mineralogist, Volume 80, pages 636–637, 1995

BOOK REVIEW

MAGMA TRANSPORT AND STORAGE. Edited by Michael P. Ryan. John Wiley and Sons, New York, 1990. xvii + 420 pages. $75.00.

Subvolcanic magma plumbing systems have received a great deal of attention from geophysicists in the past two decades. This volume is a collection of papers presented at the Symposium on Magma Transport and Storage from Source to Eruption Site, held in Washington, DC, at the 28th International Geological Congress in July of 1989. The book is divided into two parts: the first nine chapters focus on mass and heat transport by ascending and erupted magma, and the second nine discuss the geometry, mechanical character, and dynamic behavior of various types of pathways through which magma transport occurs. Authors were encouraged to expand their contributions beyond typical research papers to include relevant background, historical material, and related results.

Chapters 1 and 2 by A.C. Fowler describe mathematically a compaction model for melt transport in the asthenosphere and its applications. These chapters highlight and improve upon several oversimplifications of earlier percolative flow-matrix compaction models, which have been widely applied to the understanding of midocean ridge magmatism. Chapter 2, in particular, points out that fracture transport at the roof of a compacting layer may considerably restrict or enhance the volume of magma that can be extracted from the compacting matrix. P. Olson (chapter 3) describes the evolution of mantle plumes, including the interesting experimentally observed phenomenon of solitary waves, which may develop in plume tails and which can dramatically increase the velocity at which fresh uncontaminated material from the plume source may reach the plume head. J.A. Whitehead and K.R. Helfrich (chapter 4) consider further the role of these solitary magma waves in diapirism at midocean ridges. In this chapter the authors combine recent experimental and theoretical fluid dynamic results with the observed segmentation of spreading centers at ocean ridges to develop an integrated model of diapiric magma flux at midocean ridges. G.N. Riley, Jr. and D.L. Kohlstedt (chapter 5) summarize experiments designed to simulate the migration of melt through a polygranular olivine matrix at elevated T and P. Their data show that porous flow of melt through a solid matrix under mantle conditions may be rapid and can be experimentally investigated. P.M. Bruce and H.E. Huppert (chapter 6) mathematically model solidification and melting along the margins of dikes during laminar flow of basaltic magma. The results bear on the longevity and spatial distribution of vents along fissure systems and indicate that wall rock temperature and dike width are important controls on the nature of fissure-fed eruptions. D.L. Turcotte (chapter 7) addresses theoretically the mechanics of laminar and turbulent flow of basaltic magma through dikes. He finds that viscous dissipation and adiabatic decompression of basaltic melts counter heat loss to cold wall rock and that basalts moving through dikes wider than ~1 m will melt and assimilate the wall rock. K.H. Wohletz and G.A. Valentine (chapter 8) illustrate high-speed supercomputer simulations of explosive eruptions. They suggest that future endeavors in the field will provide much needed insights on the nature of nonlinear flow phenomena that control the eruption style and hence the distribution and physical properties of pyroclastic deposits. M.P. Ryan, N.G. Banks, R.P. Hoblitt, and J.Y.K. Blevins (chapter 9) present measurements of in situ thermal properties of Mount St. Helens eruptive products. By acquiring temperature-depth profiles at two points in time and extrapolating the observed cooling history back to the time of emplacement, the thermal diffusivity of the pyroclastic material comprising a particular eruptive unit and its emplacement temperature may be estimated.

To begin part II, A. Nicolas (chapter 10) discusses theoretical and field evidence for a dominantly hydrofracture mode, rather than porous flow mode, of melt extraction beneath midocean ridges. The structure of ophiolites suggests that hydrofracturing in melting asthenospheric diapirs focuses melt into a zone ~20 km wide, which may undergo compaction and melt extraction to form narrow discrete magma chambers below the ridge axis. M.P. Ryan (chapter 11) summarizes geophysical data that provide a remarkably comprehensive and integrated picture of the magmatic plumbing system beneath Iceland. Adiabatic melting in the core of the Iceland plume forms an interconnected melt network; porous intergranular flow outward and upward from this region supplies magma to the roots of the neovolcanic zones, and these zones reflect the loci of diapirs spaced ~50 km apart that feed magma directly into crustal chambers. Finite-element modeling has been included to elucidate crustal level interactions between the adjacent central vent complexes that ultimately control the nature of magma discharge at the surface. J.A. Ewart, B. Voight, and A. Bjornsson (chapter 12) present the results of geodetic surveys of surface deformation associated with the Krafla caldera in Iceland over a 10-yr period. Superimposed on steady inflation of the caldera floor were at least ten deflation-depressurization events related to increased seismicity and dike injection into through-going fissure zones. The emerging model is one of numerous small magma chambers interconnected by conduits that act as valves, draining and depressurizing the entire shallow magma reservoir. H. Sato and I.S. Sacks (chapter 13) use laboratory measurements of seismic velocities in solid and partially molten anhydrous peridotite to infer a generalized model of magma generation in the upper mantle. Their results suggest that decompression of rising solid asthenosphere causes partial melting to be confined to narrow regions beneath midocean ridges. In subduction zones they postulate that dry solid peridotite persists in the mantle wedge, where its solidus is exceeded only locally because of the influx of H_2O from subducted crust. H.M. Iyer, J.R. Evans, P.B. Dawson, D.A. Stauber, and U. Achauer (chapter 14) compare detailed seismic tomography results from the Long Valley caldera and the Newberry shield volcano. Data suggest that large silicic systems such as Long Valley are underlain by voluminous (10^2–10^3 km^3), deep (7–28 km!), partially molten magma reservoirs, whereas volcanoes such as Newberry have dense, high-velocity rocks (gabbroic intrusions) extending to lower crustal depths and only a small magma chamber (of a few km^3) beneath the volcanic summit. The authors conclude that the large silicic systems are stimulated through melting of lower crust by injection of basalt, although basaltic andesite dominated systems (e.g., Newberry) are fed by repeated small intrusions of basalt, most of which solidify at depth, but a few of which generate small rhyolitic magma bodies at shallow crustal levels. E.T. Endo, D. Dzurisin, and D.A. Swanson (chapter 15) describe seismic and tiltmeter measurements documenting the ascent of dacitic magma related to dome-building eruptions at Mount St. Helens. In conjunction with volume estimates of these eruptions, this study provides preliminary constraints on the depth to the source region, depth of eruptable magma residing above the source, the conduit radius above the source, and ascent velocity of the magma. K. Ishihara (chapter 16) documents tiltmeter data related to inflation-deflation phenomena at the andesitic Sakurajima volcano, Japan. The depth range of the shallow magma reservoir beneath the summit crater is constrained. The author suggests that degassing-bubble growth contributes to observed inflation-deflation and infers that rapid pressure decreases associated with deflation and eruption reflect the outbreak of stored volcanic gases. J.B. Murray (chapter 17) explores high-level magma transport at Mount Etna volcano based on measured ground deformation. This study reveals that no confined magma chambers exist within the Mount Etna edifice and that the common flank eruptions are fed by radial dikes whose geometry is controlled by local topography and stress fields. J.W. Hughes, J.E. Guest, and A.M. Duncan (chapter 18) examine historical eruptions from Mount Etna since A.D. 600. They find changes in the volume, crystallinity, and distribution of lava flows that reflect varying magma supply and magma pressure within the shallow plumbing system of this volcano.

It is difficult for most petrologists to keep abreast of important results arising from these diverse and sophisticated lines of research. In this light, the book surpasses its goals by providing a wealth of useful material for specialists and nonspecialists alike. There is a great deal of new original research along with much commentary on why and how these studies are being pursued, and each is placed into context with other types of investigations. Specialists will find rigorous documentation of the mathematical models and methods. The references are current through 1989, and in rare instances even 1990 papers are cited. This volume is beautifully typset and abundantly illustrated with many color plates. Michael Ryan is to be congratulated for his superb editing.

Magma transport and storage exert strong controls on the physical development of magmas residing in volcanic plumbing systems. Petrologists often use only geochemical and mineralogical data to model the evolution and intensive parameters of magmas. I would venture to say that most would benefit in their appreciation of how magmas behave physically from the material in this volume.

Bradley S. Singer
Université de Genève