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Book Review

Timescales of Magmatic Processes: from Core to Atmosphere, Eds. A. Dosseto, S. P. Turner and J. A. Van Ormans, Wiley-Blackwell, 2011; ISBN: 978-1-443-3260-5 (Cloth), ISBN: 978-1-4443-3261-2 (pbk)

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Typing the key-word "magmatism" while searching for books returns hundreds of results. There are many books in which authors consider various topics related to magmatism's nature and origin, its connection to tectonics, metallogeny, mineralization, its regional development or its expansion during selected geological periods. Edited by Anthony Dosseto, Simon P. Turner and James A. Van Orman, the book "Timescales of magmatic processes" concentrates on a particular topic which is crucial for understanding every magmatic process that ever took place anywhere—namely, the timing of the process. Choosing this particular aspect is a great, completely new idea, which has no counterpart in previously published books. Even though undoubtedly rapidly growing amounts of research and data makes the subject sufficiently mature to warrant an overview, the topic selection itself deserves special respect. This unique book will certainly be noticed and used by the broad scientific community.

The book contains extensive Introduction, written by the editors. Antony Dosseto and Simon P. Turner are reputable experts on isotope and thermal constraints, and James A. Van Orman is an expert on diffusion constraints on the rate of magma generation and ascent. The Introduction is followed by 11 chapters, co-authored by 20 outstanding professionals from 15 scientific institutions recognized worldwide.

Chapter 1 addresses early differentiation of the Earth and Moon. G. Caro and T. Kleine introduce ^{182}Hf-^{182}W and ^{146}Sm-^{142}Nd, which are crucial for chronological constraints on major episodes, like core extraction, its re-equilibration with a magma ocean, mantle and crust differentiation, etc. Determination of the timing of all those processes requires precise knowledge and understanding of all of them. Authors present areas where present knowledge can give a more definitive evaluation of the timescale, and those where our incomplete knowledge makes the estimation less precise. A genetical relation of the Earth and Moon is obvious, as the latter is a product of a giant collision of an embryonic protoplanet with the proto-Earth, so the timescale of Earth accretion and segregation is shown in relation to Moon.

The next two chapters concentrate on the timescale of melt production. The problem is examined with use of two tools. The authors of chapter 2, J. A. Van Orman and A. E. Saal, explain the control of the diffusion of trace element fractionation (with special emphasis on the U-series) as a tool to extract information on the melting rate in the mantle. They show a set of models, from simple ones to the more developed and more realistic. Some of them, applying diffusive fractionation of U-series isotopes, seem to be consistent with physical models of adiabatic decompression melting. The models are critically evaluated. The way they are discussed is very comprehensive and approachable. The authors give an overview of advantages and limitations resulting from existing experimental databases or from overlapping signatures of natural processes taking place during magma generation.

The problem is continued by B. Bourdon and T. Elliott in chapter 3. They further strongly

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emphasize the role of U-series analyses, which can provide constraints on other modes of mantle melting, e.g., isobaric heating and flux melting. Consequently the analysis of U-series isotopes can ultimately give pieces of information about mantle upwelling velocities and contribute to our understanding of mantle plumes.

After the generation phase, it is time to concentrate on the problem of magma ascent, and this problem is considered at various levels of generality in the next three chapters. In chapter 4, Craig O'Neill and Marc Spiegelman point to a variety of processes accompanying magma migration, from micro-scale interactions to larger fluxes. Despite the processes' complexity, their individual aspects can be described with use of common formulations. Thus mass and momentum conservation equations are presented, describing porous or channeled flow in deformable media. Further constitutive relationships to model construction of natural system occurring beneath a mid-ocean ridge or other magmatic environments are shown. The problem becomes more complicated when various aspects of magma ascent are introduced into one model. The authors perfectly guide the reader, showing the merits of many individual models and the lack of any general model.

As in the chapters about melt generation, the usefulness of uranium-series isotopes is presented again by S. P. Turner and B. Bourdon in chapter 5. This time the tool is used for determination of the timescale of melt transport from mantle to crust. Isotopic disequilibria in MORB, OIB and IAB are principal sources for estimation of the rate of the melt ascent, which is relatively fast. It also makes it possible to make a conclusion about the way the melt is transported, e.g., as channeled flow. As in the previous chapters, numerical simulations strongly support the presented ideas.

The last chapter on rates of magma ascent gives an excellent summary on the present knowledge on constraints from mantle xenoliths, and is presented by S. Y. O'Reilly and W. L. Griffin. Within the tools used for obtaining needed information, once more diffusion plays an important role. Namely, the rate of magma emplacement can be estimated from element diffusion profiles in xenolith minerals. The authors also place much attention on the observation of microstructures, which are equally necessary.

Again, diffusion can be used as a tool for determination of timescale of equilibration and re-equilibration processes during magmatic crystallization. Fidel Costa and Daniel Morgan report about time constraints derived from magmatic crystals, both authors being well known from extensive research done on the subject. In their chapter, they give an extended review of the problem from theory, experiments, and natural observations, up to a practical guide of analytical techniques and the data derived from them and processed toward models. The authors present the atomistic description of diffusion and the mathematical formulations resulting from it, providing the reader with a useful background. An important part of the text is related to the experimental determination of diffusion coefficients and the parameters in control of them. An interesting comparison is done by the authors between timescales calculated from zoning patterns and determined by other techniques, e.g., U-series measurements.

Discussion of the timescale of magma differentiation is continued in the next chapter. The timescale of different mechanisms of magma differentiation can be quantified and modelled with use of data from U-series measurements, as is shown in a very convincing manner by A. Dosseto and S. P. Turner. This time, the data are extended further on highly silicic compositions. Different mechanisms of magma evolution, like crystallization or mixing, have been considered. These processes are reflected in both single crystal geochemistry as well as whole rock geochemistry. Consequently, the authors show methods of data processing in both cases. The chapter is supplemented by two very useful appendices providing equations for some models, *inter alia*: discrete magma recharge, continuous crustal assimilation and crystallization.

Extension of the issues discussed in the more silicic compositions leads to the presentation of the process of crust melting and ensuing processes: melt segregation, migration, etc. These processes determine the chemical differentiation of the crust. Their quantification and modeling is a matter of a combined data set coming from field observations and experimental studies. Discussion of the results of experimental studies are of particular importance in this chapter, written by T. Rushmer and K. Knesel.

Timescale constraints are discussed separately for deep- and mid-crust and upper crust. The authors give a review of static and dynamic experimental results, pointing to particularly useful data, such as the isotopic and trace element composition of a melt. They propose to use both as a function of rates at which melt is formed. However, they also emphasize structural factors, which exert control on melting process, as well as melt segregation and emplacement. The chapter brings the multi-aspect discussion on present knowledge, and formulates the future progress in this field.

Dynamic processes leading to large silicic magma bodies do not terminate with the melt accumulation. Olivier Bachmann acquaints the reader with the whole chain of processes taking place during the growth and maturation of such bodies: recharge, partial melting, convective overturn, etc. Once more, the radiometric dating and diffusion profiles can contribute to the modelling of time-dependent physical processes. Knowledge of the rate of all those processes can be crucial for accurate prediction of emptying such reservoirs, e.g., for prediction of supervolcanic eruptions.

The eruption style depends, *inter alia,* on the volatile content of the erupted magma. Timescales of magma degassing is the last subject in the book, handled in a perfect way by K. Berlo, J. E. Gardner and J. D. Blundy. They explain the importance of, and show step by step the mechanism of, the process in an open and in a closed system. Timescales of the process are determined on the basis of diffusion or with the use of radionuclides. As ore deposits are very much dependent on a volatile evolution path, this chapter will be of special interest for all geologists doing research on fluid-related mineralization.

In summary, the book is an excellent guide for everybody dealing with magmatic processes. This is also the first guide constructed on such a highly needed subject—the evaluation of the time of numerous magmatic processes, considering numerous aspects of the problem and various subjects related to the problem. All of them are presented in very accessible way in all 11 chapters. The knowledge is carefully selected from numerous papers, presenting best review of what has been written. References give further possibility to look for more details. Certainly this book is worth recommendation, not only as a valuable handbook but also as a book which offers new hints for further research on the problems mentioned within.