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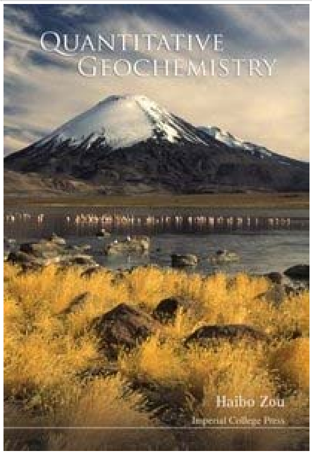
Book Review: Quantitative Geochemistry

Quantitative Geochemistry by Haibou Zhou. Imperial College Press. 2007, 304 pp. ISBN 1860946461



Just as every one of us always has an opinion about the meaning of life, death or politics, it is quite likely that each of us has his or her own unique view of what geochemistry is. This is confirmed by the ever diversifying member-base of the Geochemical Society. So when I was asked to review Haibou Zhou's "Quantitative Geochemistry", I was very intrigued. Zhou's "Quantitative Geochemistry" represents just one specific facet of geochemistry, that is, the use of trace elements or isotopes as tracers in understanding igneous processes involving melting, crystallization or mixing. This is not a book about environmental geochemistry, petrology, kinetics, thermodynamics or physical geochemistry. It is instead an exhaustive compendium of tracer box modeling in the context of magmatic processes. High temperature geochemists are all keenly aware of the basics of tracer box modeling, which are based simply on writing out conservation of mass equations. Of course, given all the possible physical scenarios by which melting or crystallization can occur, analytical representations of mass balance can become quite complicated. Almost every geochemist has spent countless hours writing out and deriving such equations for their specific petrogenetic case study. What "Quantitative Geochemistry" offers is the most complete compendium of analytical solutions to mass balance and transport models relevant to igneous petrology. "Quantitative Geochemistry" is essentially a book of recipes.

Some detailed comments regarding content are in order. In Chapters 1 and 2, Zou brings together many of the classical mass balance equations (laid out decades ago by such luminaries as Gast, Shaw, and many others) used to model trace element fractionation between melts and their residual solids. Zou provides the principles of batch and fractional melting, which are concepts that every student of geochemistry is or should be familiar with. Zou builds on these simple formulations by considering non-modal (eutectic) congruent melting, variable partition coefficients (though there is no discussion about the physical chemistry of element partitioning), and finally incongruent melting, concepts that are often not fully treated in most introductory textbooks. In Chapter 3, Zou builds on the work of McKenzie on dynamic melting, wherein the rate of melting is limited by porosity. In Chapter 4, Zou outlines equations for open system melting. Zou's view of open system melting here is somewhat simplistic, focusing primarily on the case in which the system is simultaneously undergoing melting and being modified by the addition of batch or continuous increments of melts or new solids. There are no discussions of the more realistic, and admittedly more complicated chromatographic and reactive processes. Chapter 5, jumps directly to the use of Uranium series disequilibria in constraining melting rates. Zou starts off with a brief review of the principles of Uranium series decay and then couples the radioactive decay equations with equations describing melting rates. Chapter 6 discusses trace elements and isotopes in the context of magma mixing and crystallization, laying out the classic assimilation-fractional crystallization equations of DePaolo and more. Chapter 7 is entitled "Inverse geochemical modeling", but what Zou means here by "inverse" is not the concept of least squares minimization of residuals but rather using trace element concentrations in magmas to extract infer information about melting degree (or melt fraction) or partition coefficients (as opposed to Chapters 1-4 wherein elemental concentrations in magmas are forward-modeled based on assumptions of melting degree and partition coefficients). In my opinion, the first seven chapters are the forte of "Quantitative Geochemistry". I am happy to have this book just for Chapters 1-7 and I think many readers might agree.

I am less excited by the remaining chapters. The remaining chapters seem to be like a mix of good ‘ol Texas barbecue and California tofu burgers. Each of these chapters are useful in their own right, but don't expect any rhyme or reason in the choice of themes. For example, chapters 8-9 are primarily technical chapters about error propagation and linear least squares fitting. Although there are clearly many other books that lay out these concepts better, these chapters are still welcome as they provide the reader a primer into these concepts. Chapters 10 and 11 are probably only of interest to mass spectrometrists, and in particular, isotope geochemists. It's not clear to me why these chapters are even in this book. They may,

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however, still be of some use as they summarize some of the empirical fractionation "laws" used in mass spectrometry. Chapter 11 discusses the concept of "spiking" or isotope dilution; while this is welcome, it would seem that such a chapter would be better relegated to an appendix. Chapter 12 is about the various ways that the decay of U isotopes to Pb can be mathematically presented. This chapter is laid out in the form of FAQs (Frequently Asked Questions by students), i.e., "Section 12.1 Why is the Tera-Wasserburg Concordia diagram concave upward" or "Section 12.2, Why is the conventional Concordia plot concave down?". Once again, Zou is commended for highlighting basic, but perhaps often overlooked, concepts and features of the U-Pb isotope system, but what is missing is any discussion of the U-Pb system in the context of data or geologic and cosmochemical problems. The discussion of the U-Pb equations comes across more like a fun math game. Chapter 13 is entitled "Geochemical kinetics and dynamics" but is too short and scattered to be of much use. There is a very brief discussion of diffusion, an almost non-existent discussion of advection (despite an individual section allotted to this topic), a brief discussion of bubble growth, and finally, an irrelevant discussion of the projectile motion of a volcanic bomb with a little drag thrown into it. I do, however, like the idea of ending the book with something violent like a volcanic bomb flying through the air.

In summary, this is a book that is well worth your money if what you want is a compilation of mass balance and box model equations for mantle melting. Believe me, it will save you a lot of time in re-deriving all these equations or searching through the literature for published solutions. In this regard, this is a valuable and highly recommended book (Chapters 1-7). The book, however, is not designed to be a textbook for students. It is written very tersely. There is little to no discussion about petrology (phase equilibria or thermodynamics), the physical chemistry of element partitioning, geologic processes, or the physics of melting and melt transport. Although radioactive decay equations are presented in this book, one would do well to have a big picture understanding of isotope geochemistry before examining Zou's work. There is little discussion about the principles of radioactive decay or their applications to geological problems. Some topics that are missing or minimally discussed and that I thought should have been in a book focused primarily on tracer box modeling include: chromatographic processes, melt-rock reaction, reaction rates and kinetics, and reservoir box modeling. It would also have been good to present equations in more intuitive ways, such as by presenting dimensionless numbers to describe competing processes. These criticisms are certainly not meant to take away from my overall very positive view of this book. At the end of the day, it is hard to put everything into one book.

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