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Book Review

FLUID-FLUID INTERACTIONS. Axel Liebscher and Christoph A. Heinrich, Eds. (2007) Reviews in Mineralogy and Geochemistry, 65, 430 p. Mineralogical Society of America, Chantilly, Virginia. ISBN 978-0-939950-77-5. $40.00.

That two or even more coexisting fluids may occur in geological systems is something that is very well known but rather little understood. While it is true that from a thermodynamic point of view fluids that are in equilibrium are effectively the same fluid, for any understanding of irreversible processes in nature it is essential to appreciate what happens when there are different fluids of different compositions, densities, and transport properties present in a system.

This volume effectively brings together experimental data, theory, and results from natural systems for a wide range of fluid-fluid systems, and it is particularly effective at juxtaposing complementary approaches and emphases that have been developed by researchers in different fields. At last we have a one-stop shop to get up to speed with the relevant data and approaches, whatever the system. It is essential reading for anyone who hopes to understand almost any geological process, with the possible exception of meteorite impact.

The volume is mainly, but not exclusively, concerned with immiscibility among relatively low-density fluids, and the introductory chapter by the editors serves to set the scene and to outline the different types of phase diagrams that can result. These authors also highlight some of the inconsistencies in usage that have developed between different specialists, and in particular the very specialized (i.e., strictly incorrect) terminology used in studies of oceanic hydrothermal systems. Specific chemical systems are summarized by Liebscher in chapter 2, and this provides an invaluable synthesis of a wide range of experimental literature, particularly that documenting the effects of salts in extending the conditions over which 2-phase behavior can be expected in H_2O or H_2O-CO_2 fluids. The theoretical treatment of immiscible low-density fluids, and the successive formulations of Equations of State appropriate for describing fluid properties under crustal conditions, are set out in meticulous detail by Gottschalk in the third chapter. In addition to providing a general theoretical basis, he has also set out in the appendices revisions and corrections to some widely used published treatments of the derivations, although the reader still has to trawl the literature for specific constants.

Much of the rest of the volume is concerned with immiscibility in specific settings. A pair of papers from Thompson, Hack, and Aerts deal with immiscibility in magmatic systems. The possible existence of silicate melt immiscibility as an explanation for coexisting basic and acid magmas, for example, has been discussed for over a century, but the first paper, dealing with anhydrous systems, succeeds in bringing out the essence of the arguments and demonstrating the theoretical basis for occurrences of immiscibility, while explaining why it is an unusual phenomenon in natural systems. In addition to silicate-silicate immiscibility, immiscibilities between melts with other components, notably carbonate-silicate and phosphate-silicate systems, are also reviewed. The second paper concerns hydrous systems and is one of several chapters in the volume that deal with aspects of water in melts. Of particular interest is a brief review of the current state of investigations into the identification of critical points between silicate melt and water at mantle pressures. This is of central importance to understanding how volatiles may transport slab components into arc magmas, because the transport signature of a supercritical silicate-water fluid will be quite different from those of an aqueous fluid.

Magmatic melt-fluid interactions also figure in other chapters, and indeed there is a certain degree of overlap in the content. Webster and Mandeville tackle primary magmatic fluids in a volcanic context, applying many ideas and results that were originally developed for ore deposit studies and showing how these can be related to observations of volcanic rocks. This is a field where developments in observations of volcanoes are beginning to provide tests for ideas about fluid separation developed from experimental and theoretical results. Magmatic-hydrothermal ores themselves are the subject of a chapter by Christoph Heinrich, which discusses the way in which metal enrichment arises and emphasizes the importance of relatively shallow processes for generating the extreme salinities that characterize many magmatic ore systems.

Fluid processes in magmatic hydrothermal systems figure in two chapters. Arnorsson and colleagues outline the range of fluids characteristic of geothermal systems. These are dynamic settings where liquid and vapor phases are present but may not strictly occur in equilibrium, and the chapter ranges over many aspects of fluids in geothermal system, based on an enormous amount of direct observation from geothermal exploration and production. Seafloor systems have also undergone extensive research over the past 25 years, and fluids with variable salinities and volatile concentrations have been widely reported from vents. A chapter by Foustoukos and Seyfried evaluates the role of phase separation in their generation, drawing on both field observations and experiments.

The best understood setting in which fluid immiscibility occurs is hydrocarbon basins, and some aspects of these are reviewed in a chapter by Pedersen and Christensen, in which the discussion of multicomponent hydrocarbon fluids brings a new dimension to the volume. In contrast, metamorphism is a field in which immiscibility has been largely ignored, perhaps because much of what we know about metamorphic fluids comes from thermodynamic calculations, which are generally unable to recognize it. Immiscibility must be particularly important in the metamorphism of carbonate rocks, where salinity is driven to very high levels by hydration reactions, and these provide the main focus for the final chapter by Wilhelm Heinrich.

While most of the chapters refer to specific geological settings, there is also a chapter dealing with the numerical simulation of the effects of two-phase behavior on flow in hydrothermal systems, by Driesner and Geiger. While the diversity in detail among superficially similar hydrothermal systems might appear to make the chance of successful modeling seem unlikely, it is reassuring that they report that first-order behavior of complex hydrothermal systems can in fact be modeled quite successfully. This chapter appears to set the stage for much further work in the near future.

Overall, this volume is an outstanding addition to the series and succeeds in bringing together an enormous range of research, spanning modeling, field studies, and experimentation, that addresses the behavior of systems in which more than one fluid phase may be present. It is perhaps unfortunate that there is no chapter specifically on fluid inclusions, since these are referred to in many chapters as providing critical evidence to demonstrate fluid immiscibility in nature, but this is a minor criticism. Essential reading and reference for anyone whose research concerns geological fluids.

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