

BOOK REVIEW

FLUID-ROCK INTERACTIONS DURING METAMORPHISM. Edited by J. V. Walther and B. J. Wood. *Advances in Physical Geochemistry*, Vol. 5, Springer-Verlag, New York, 1986. 218 pages. \$44.00.

This volume presents current theories on the chemical and physical interactions between metamorphic fluids and the rocks they pass through. The role of fluids in metamorphic processes has been only recently recognized, and the eight papers presented here represent diverse opinions, yet comprehensive coverage of prevailing lines of work.

Crawford and Hollister in Chapter 1 discuss how the study of fluid inclusions has contributed toward understanding metamorphic processes. They suggest that fluid inclusions do represent some metamorphic fluids in that compositions of fluid inclusions inferred from density measurements correspond to those calculated from mineral assemblages. In addition, the study of fluid inclusions has contributed to the recognition of phenomena such as the occurrence of immiscible fluids in metamorphic environments. They present a theory of the origin of CO₂ in granulites that appeals to the extraction of H₂O by removal of a granitic melt, leaving a residue of pure CO₂ or N₂ behind in healed fractures.

Chapter 2 by Newton covers fluids commonly found in granulite-facies metamorphism. Some discussion of the properties of CO₂ under granulite pressure-temperature conditions is included, followed by the effects of other components on CO₂ fluid-inclusion properties. He lists three hypotheses of CO₂ genesis in granulites, including the hypothesis of Crawford and Hollister in Chapter 1, as well as the possibility of vapor-absent metamorphic conditions, supported by typical low H₂O fugacities in granulite metamorphism, and the possibility of CO₂ streaming.

Chapter 3 by Ferry summarizes his (and others) reaction-progress techniques for monitoring the quantity of fluid-rock interaction during metamorphism. He lists methods for determining mineral-alteration reactions from the rock and discusses how to determine reaction progress through modal abundances in the rock. An underlying assumption of this approach is that the final fluid is in equilibrium with the rock; an assumption addressed later in Chapter 8. Case studies of several metamorphic terranes are presented where calculated water-rock ratios in carbonates and metacarbonates vary from 1 to 10. This range of values has not been demonstrated in rock types other than carbonates to date. A comparison of this method of obtaining water-rock ratios with the isotope method of Taylor is also included.

Wood and Walther in Chapter 4 discuss circumstances under which fluid convection during regional metamorphism may occur. They conclude that convection may operate only under conditions of hydrostatic fluid pressure and note that regional metamorphism almost always occurs at depths greater than 6 km where lithostatic conditions are more probable. Hence a single-pass fluid is most likely, and large water-rock ratios (W/R) will not be generated under most regional metamorphic conditions. They suggest that H₂O in carbonates comes from progressive metamorphism and dehydration of pelites and that observed W/R in carbonates can be accounted for by single-pass fluids if carbonates compose less than 10% of the metamorphic pile. They point out that convection and hence large W/R may be more common in contact metamorphism and suggest additional methods to calculate W/R from redox equilibria and alkali exchange between micas and fluids.

Chapter 5 by Yardley again outlines factors controlling fluid pressure and fluid flow during metamorphism and interprets veins in the Connemara Schists in Ireland accordingly. He attempts to distinguish between fluid produced through reaction progress and flushing from external sources. Factors determining the formation of spaced fractures and veining are considered, and the quartz veins in the Connemara are concluded to represent major pathways of fluid loss through one-way fluid flow. Very high fluid-rock ratios on the order of 100 are calculated for the andalusite-rich portions of retrograde Knockaunbaun veins.

Chapter 6 by Gregory details oxygen-isotope systematics in mineral pairs with application to Precambrian iron formations. The effects of prograde and retrograde metamorphic events on the isotopic signature of mineral pairs in open and closed systems is considered. He divides Precambrian magnetite-chert ¹⁸O pairs into equilibrium (deformed terranes) and disequilibrium (undeformed terranes) arrays. The equilibrium arrays may represent diagenetic rather than surface events and could correspond to disequilibrium array patterns subsequently equilibrated at higher temperatures. The disequilibrium pairs imply that the rocks behaved as open systems. It is evident that multistage oxygen-exchange events have occurred, and although $\delta^{18}\text{O}$ values of cherts are usually assumed to indicate something about either temperatures of formation or $\delta^{18}\text{O}$ of the ocean, it is possible to account for all the observed heterogeneity by appealing to diagenetic events rather than any paleoclimatological changes.

Ridley and Thompson in Chapter 7 discuss how kinetic processes influence mineral and rock textures during crystallization under metamorphic conditions and attempt to determine pressure-temperature-time paths of metamorphism based on observed textures. They estimate the magnitude of overstepping before nucleation by assuming that disagreements in experimental curves for mineral-equilibrium boundaries are all due to *P-T* overstepping and obtain estimates of 50–100 deg. They address rate-controlling steps in grain growth after nucleation and suggest that Wood and Walther's universal reaction rate is sufficient if diffusion control is rate limiting, but not if interface-reaction control is rate limiting.

Walther and Wood in the final chapter discuss mineral-fluid reaction rates over a wide range of temperatures from 25°C to metamorphic temperatures. They emphasize that the rates of mineral-fluid reactions must be determined in order to address whether sufficient time is available for equilibrium to be attained. The single-rate equation previously proposed by Wood and Walther for silicate dissolution is not adequate at low temperatures where rates differ by approximately five orders of magnitude at 25°C and are pH dependent. Therefore, a compensation law is proposed to account for a transition from low to high temperatures. Data support the universal-reaction-rate law in metamorphic temperature regimes, and it can be concluded that reaction rates are fast enough for rocks to buffer the assumed amounts of fluid flowing through the systems. In other words, these results are consistent with the calculated water-rock ratios for carbonate systems.

Overall, this slim volume represents an up-to-date look at the field of fluid interaction in metamorphic petrology, and I recommend it to those interested in this subject.

TERESA SUTER BOWERS
Massachusetts Institute of Technology