

Oxygen diffusion and exchange in dolomite rock at 700 °C, 100 MPa

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ABSTRACT

In contact-metamorphic environments dolomite commonly breaks down to calcite + periclase + CO₂ as a result of the infiltration of H₂O. The transport and exchange of oxygen in dolomite rock during the breakdown reaction were examined experimentally by reacting a cylindrical core of Reed Dolomite with isotopically enriched water having the composition HD¹⁸O_{0.5}¹⁶O_{0.5} at 700 °C and 100 MPa for 29 days. Reaction products formed along grain boundaries, fractures, and on the outside surface of the core. Some dolomite grains became enriched in Fe as a result of replacement of the host dolomite. Extensive voids are found in the grain boundaries as a result of the ~25% loss in solid volume during reaction. There are also pores, ~1 μm in diameter, in the dolomite, notably in the vicinity of the replaced dolomite. The distribution of ¹⁸O in the dolomite and reaction products was used as a tracer of the transport and exchange of O during reaction. Electron probe microanalysis (EPMA) and secondary ion mass spectrometry (SIMS) analyses showed pervasive infiltration of fluid along grain boundaries and fractures, growth and isotopic exchange with products of reaction, and diffusion of ¹⁸O into dolomite grains. The fluid infiltrated efficiently along grain boundaries to the dolomite grain surface. The host dolomite shows an enrichment in ¹⁸O along grain boundaries, indicating a diffusive exchange with the fluid. An estimate of the diffusion coefficient of oxygen in dolomite, determined from ion probe spot analyses, gives $D \approx 1 \times 10^{-12}$ mm²/s. This value is comparable to the oxygen diffusion coefficient for calcite in an H₂O-rich fluid. Mass balance of O in the experiment (including dolomite–fluid exchange, the amounts of neomorphic reaction products, and the fluid components) indicates that the reaction products have a ¹⁸O concentration only about half that of the fluid. Ion probe spot analyses of calcite from both the center and the edge of the core have the fraction $F = {}^{18}\text{O}/({}^{18}\text{O}+{}^{16}\text{O})$ of 0.14 ± 0.1 , whereas the value calculated for the fluid is 0.31. The measured F values of calcite are intermediate between the initial F values of starting water and dolomite, indicating that the reaction products record a mix of both dolomite- and fluid-derived oxygen. The products reached about 45% of isotopic equilibrium, similar to the extent of the mineral–fluid reaction. The Fe-rich, replacement dolomite near the core edge has an elevated value of $F = 0.02 \pm 0.002$, 10 times the value of $F \approx 0.002$ for unreacted dolomite, but less than the value for the calcite. The distribution of ¹⁸O in the minerals indicates that the breakdown and replacement reactions were faster than O diffusion in dolomite.

Keywords: Dolomite, oxygen isotope, exchange, diffusion, contact metamorphism, SIMS