American Mineralogist, Volume 85, pages 14–21, 2000

Microstructural characterization of metamorphic magnetite crystals with implications for oxygen isotope distribution

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ABSTRACT

The microstructures of magnetite crystals in three samples from a single outcrop of granulite-facies marble were characterized by transmission electron microscopy (TEM) to determine how exsolution history can affect physical properties and mineral reactivity during retrograde metamorphism. The microstructure of sample 90LP9 consists of dislocations, dislocation arrays (with dislocation spacings of 100 to 500 nm), and linear channels filled with layer silicates. Acid etching and ion milling of polished 90LP9 magnetite grains show dislocation arrays clustered near grain boundaries with rheologically hard magnetite, diopside, and monticellite, but rarely near grain boundaries with softer calcite. Sample LP204-1 magnetite grains contain coherent {100} Al-Mn-Fe-spinel precipitates (~40 nm diameter, ~1–3 nm thick, ~10^4 platelets/μm^3) and very few dislocations. Larger, more widely spaced spinel precipitates are present in a third sample, 94AK3. Extremely low dislocation densities in powders of LP204-1 and intermediate dislocation densities in powders of 94AK3, compared with extremely high dislocation densities in powders of 90LP9, are related to strong dislocation pinning effects by precipitates. The different exsolution behavior of the three magnetite samples is attributed to small, but important, differences in Al content. Because dislocations can provide fast pathways for exchange that enhance diffusion, especially in very slowly cooled rocks, these microstructural results may explain previously reported subgrain-scale oxygen isotopic heterogeneity in 90LP9 magnetite compared with relative isotopic homogeneity in LP204-1 magnetite.