Theory of low-temperature deuteritic oxidation with application to time evolution of ocean magnetic anomalies

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The NRM of the ocean floor is carried by titanomagnetite grains that undergo low-temperature oxidation after initial cooling. Progressing oxidation is known to generate shrinkage cracks in grains larger than approximately 5 mkm, and is suspected to control the long wavelength variation of NRM-intensity across the ocean floor. Here we develop a quantitative theory of single-phase oxidation and crack formation by solving the vacancy-diffusion equation that describes the oxidation process for spherical titanomagnetite particles, where the diffusion coefficient strongly decreases with vacancy concentration. The latter dependence has been experimentally demonstrated and is essential to explain the peculiarities of the observed variations of oxidation-degree with ocean-floor age. The calculated diffusion profiles provide the exact stress distributions inside oxidized titanomagnetite spheres, and predict a size limit for shrinkage-crack formation that agrees with microscopic observations of crack appearance in ocean-floor basalt samples. The new diffusion model provides a unified explanation of long-known experimental facts that 1) temperatures for the onset of low-temperature oxidation during laboratory heating are theoretically estimated as 200-400 °C, depending on grain size, and 2) that heating to 400-500 °C is required to obtain a sufficiently high degree of oxidation z about 0.8 for the development of high-temperature exsolution lamellae. Calculations for ocean-floor conditions quantitatively suggest that a rapid decrease of NRM intensity during the first 40 ka results from a deflection of magnetization by strong stresses that emerge in titanomagnetite grains of sub-critical sizes, and randomization of domain-state by crack formation in larger grains. This work was supported by Russian Science Foundation grant 19-47-04110401 (VS)