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A Quantitative Model for the Thermochemical Remanent Magnetization of the Ocean Floor

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Abstract

The ocean floor covers more than 70% of the Earth's surface and its magnetization patterns preserve plate tectonic motions as well as geomagnetic field variations over the last 180 Ma. The natural remanent magnetization (NRM) of ocean floor basalts is a thermochemical remanent magnetization carried by titanomaghemite and acquired during the very quick cooling of basaltic flows. Its complex nature was already recognized by Nagata and Kobayashi (1963) and triggered a large amount of rock magnetic research on thermochemical remanent magnetization. Bleil and Petersen (1983) discovered the importance of low temperature single-phase oxidation of titanomagnetite for the NRM of ocean floor basalts. Oxidation starts at the grain surface and develops an inhomogenous distribution of the vacancies whereby the outer parts of a particle are more oxidized than its inner core. The corresponding decrease of lattice constant towards the oxidized grain surface generates excessive internal stresses which can generate shrinkage cracks. Such shrinkage cracks have been observed by Gapeev and Tselmovich (1983) and were studied by Petersen and Vali (1987). The diffusion properties of oxidation in titanomagnetite have afterwards been carefully studied by Gapeev and Gribov (1990), who found that – like in magnetite – the diffusion coefficient sharply decreases with increasing oxidation parameter. Although these results qualitatively clarify many aspects of TCRM acquisition in ocean floor basalts, a quantitative model is still missing. Here we develop a theoretical framework that connects all the above details and provides a consistent model of the oxidation process in titanomagnetite grains in oceanic basalts, including the development of the stresses and generation of cracks. Using this theoretical approach also the acquisition and evolution of NRM within the oceanic crust can be studied.

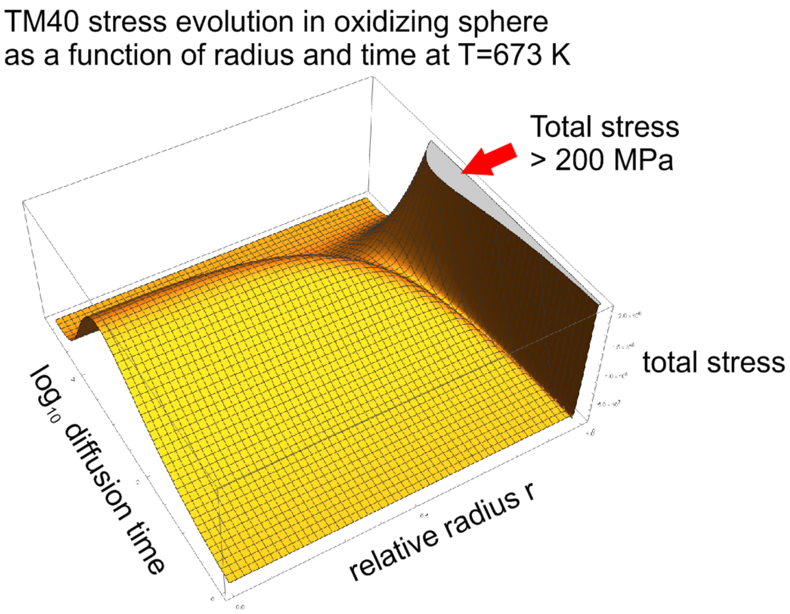

Fig. 1. Stress evolution in an oxidizing titanomagnetite sphere (TM40) as a function of radial distance and time. Note that excessive stress can develop only near the surface at a relative radius of > 0.87. Only in sufficiently large grains this can lead to fracture formation.

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