Investigation of ˜3.45 Ga rocks and single silicate crystals from South Africa as recorders of Earth's early magnetic field

Yoichi Usui[1]
[1] Earth Sciences, Tohoku Univ.

The behavior of the early geomagnetic field is key for investigations of Earth's thermal history, evolution of its atmosphere and the development of life. A major obstacle to obtaining primary remanences from the oldest terrestrial rocks is ubiquitous low-grade metamorphism which has resulted in magnetic mineral alteration and magnetic overprints of varying age. To address this problem, Tarduno et al. (Nature, 2007) proposed magnetic measurements on pristine single silicate crystals hosting magnetic inclusions separated from whole rocks. This approach yielded the oldest paleointensity data available to date based on a terrestrial TRM (see also, Dunlop, Nature, 2007). Specifically, these data indicate that Earth's magnetic field at ˜3.2 Ga was within 50% of the strength of the modern field. Here, we report rock magnetic, paleomagnetic and preliminary paleointensity results from 3.45 Ga rocks from the Barberton Greenstone Belt (Kaapvaal Craton, South Africa). We focus on an exceptionally well-preserved dacitic intrusion of the Hooggenoeg Formation. This lithology is preserved in situ and as clasts comprising stratigraphically overlying conglomerates, providing an ideal opportunity for a field test of the age and nature of remanent magnetization. Detailed progressive thermal demagnetization of the conglomerate clasts reveals a common overprint component of low unblocking temperature and a high unblocking temperature component which is directionally distinct for each clast. These data comprise a positive conglomerate test, indicating that the underlying dacitic intrusion could hold a primary magnetization. But the minimum temperature range needed to isolate the high unblocking temperature remanence (525 ˜550 C^{o}) in the clasts suggests the presence of multi-domain magnetic grains (whose presence is also indicated by magnetic hysteresis measurements). Theory and empirical data indicate that a thermoviscous overprint induced by low-grade metamorphism and carried by multi-domain grains cannot be completely thermally demagnetized, prohibiting the further use of the bulk rock to constrain the ancient field. In contrast, although total magnetization values are low, magnetic hysteresis data collected on quartz phenocrysts separated from the intrusive dacite show pseudo-single domain to single-domain characteristics. Therefore, these crystals are predicted from theory to preserve a primary TRM in the temperature range between ˜400 C^{o} and 580 C^{o}. The results of preliminary Thellier paleointensity experiments using such quartz crystals will be discussed. This study is co-authored by J. A. Tarduno (Univ. Rochester), M. K. Watkeys and A. Hofmann (Univ. of KwaZulu-Natal).