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The effects of irradiation on the magnetic properties of rock and synthetic samples

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Irradiations in space, by solar wind (SW), solar cosmic rays (SCR) (i.e., solar-flare-associated particles or solar energetic particles) and galactic cosmic rays (GCR) – the main source of space weathering of the solid Solar System bodies – may result in changes in magnetic properties of extraterrestrial materials, thus complicating the interpretation of the magnetism of meteorites, micrometeorites and lunar samples. The objective of this work was to check the effect of irradiation on the magnetic remanence and intrinsic magnetic properties of the main magnetic carriers of extraterrestrial materials: iron and FeNi alloys, Ti-rich and Ti-free magnetite, and pyrrhotite. We performed irradiation experiments on rock and synthetic samples using protons, the most abundant elements in space radiations, with energies (E_1=400 keV and E_2=850 keV) close to these of SCR protons. We also performed irradiation experiments using argon ions (E=400 keV) and lead ions (E=1 GeV or $\sim$5 MeV per nucleon) to check the degree of irradiation-induced damage compared to protons.

Corresponding rock magnetic analyses were carried out before and after irradiation experiments. Irradiation by protons produced a significant increase in coercivity of remanence (B_{cr}) in a taenite-bearing meteorite as well as in synthetic iron and magnetite. Similar effect of magnetic hardening was found in FeNi-bearing Bereba and Tatahouine HED meteorites, irradiated by argon ions. Considering the maximum penetration depth of SCR protons with $\sim$MeV energies (from μm to mm), this suggests that space radiations could result in magnetic hardening of nickel-iron bearing planetary surface materials, micrometeorites and meteorites containing regolith breccias. In the first millions years after gravitational collapse of the proto-star (early solar system), when SCR flux was far more abundant, it could result in magnetic hardening of primary chondritic material. Irradiation by heavy ions did not produce any changes in B_{cr} but resulted in changes of saturation isothermal remanent magnetization, directly related to the capacity of rocks to acquire remanent magnetization.