Sulfur isotopes of pyrite in meteorite NWA 7533 and early oxygenation event on Martian atmosphere

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Atmospheric O_2 is a key driver of the planetary biogeochemical cycles. However, its content has not been constrained for any early planets such as Hadean Earth and Noachian Mars. *In-situ* sulfur isotope compositions of pyrite in Martian regolith breccia meteorite Northwest Africa (NWA) 7533 were determined using a Camerca NanoSIMS 50L. The lithologies in NWA 7533 crystallized very early at ~4.4 Ga, representing parts of the acient Martian crust. The large mass-independent fractionation (MIF) of sulfur isotopes ($\Delta^{33}S$ up to 7.61 ± 1.47 ‰) indicates a low-O_2-content atmosphere on Mars before 4.4 Ga, similar to that on Archean-early Proterozoic Earth. A comparison with the small sulfur MIF anomalies of younger mafic Martian meteorites suggests that an oxygenation event could have occurred on Mars at ~4.4 to ~4.1 Ga. The early oxygenation could be attributed to the Martian dynamo, which generated a strong intrinsic magnetic field to prevent the escape of oxygen and thereby increased the O_2 content in early Martian atmosphere. The O_2 may be produced by water photo-dissociation or possibly life-related process. Noachian Mars could have had warm and wet climate, elevated atmospheric O_2 content and intrinsic magnetic field, more habitable than current Mars.