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Silicate Earth oxidation driven by Moon-forming giant impact

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The redox state of the bulk silicate Earth (BSE) is crucial for Earth's habitability and evolution. The oxygen fugacity (fO_2) of the BSE is more than two orders of magnitude higher than that of other terrestrial planets and the Moon. However, it is still not clear how the Earth gets more oxidized during accretion. Here we show that Si and V isotope compositions of the chondrites, Moon, and BSE reveal a dramatically increased fO_2 of the BSE after the Moon-forming giant impact. The BSE and Moon have identically δ^{30}Si higher than chondrites, while the δ^{51}V of BSE (-0.91‰) is higher than that of chondrites (-1.09‰) and Moon (-1.04‰). Theoretical simulation using experimentally determined isotope fractionation factors shows that core–mantle differentiation under reducing conditions can explain the isotopic offsets between the meteorites and the proto-Earth (and Moon), while the δ^{30}Si similarity and δ^{51}V difference between the Earth and Moon require further core segregation under oxidized conditions, which likely resulted from re-dissolution of Fe^{3+} enriched materials into the post-impact magma ocean driven by the Theia impact. Consequently, the Moon-forming impact was the key in producing the high fO_2 of the BSE, which fundamentally changed the Earth's nature in many aspects.