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Impact melting of regolith particles by micrometeorites as the main space weathering mechanism on silicate airless bodies

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Surface exposure of lunar soils produces their optical maturation resulting from change in structure and composition of regolith particles, namely, formation 1000 Å-thick amorphous rims on the particle surfaces containing grains of reduced iron of nanometer sizes (nFe^0). Being reducing and amorphization agent, solar wind does not favor association of isolated Fe^0-atoms in grains at low temperatures typical of the surfaces of atmosphereless bodies. Mobility of Fe^0-atoms high enough for their association into grains is achieved only at elevated temperatures provided by meteorite impacts, most of them being due to projectiles $<$1mm. On airless bodies, high temperature itself is sufficient for reduction of Fe^{2+} without other reducing agents such as solar wind. In solid phase, diffusion of Fe atoms is too slow and nFe^0 grains can form only at long cooling times characteristic of $>$m impacts, so subsolidus reduction of Fe does not produce nFe^0 grains in most frequent small impacts. Our calculations show that such grains can be formed in impact melt (due to high diffusion rates in liquid phase), cooling times for melt produced by submicron projectiles being just sufficient for formation of nFe^0 grains of the observed average diameters 60 Å. Mass of impact melt exceeds the mass of condensed impact vapor by an order of magnitude, which makes impact melting much more effective for maturation than vapor condensation. Thus, impact melting can provide the observed characteristics of mature soils without any other space weathering factors, so it may cause regolith maturation on bodies shielded from solar wind irradiation, such as Mercury, and on asteroids, where projectile velocities are sufficient for impact melting but not for evaporation.