In this study, we investigate the effects of space weathering on the moon using Atom Probe Tomography (APT). We show that APT is a powerful tool for characterizing the composition and texture of space weathering products in ilmenite from Apollo 17 sample 71501. Two of the studied nanotips sampled the top surface of the space-weathered grain, while another sampled the deeper and unaltered part of the ilmenite. The different distribution of space weathering products between the two nanotips is due to sampling different adjacent grain volumes, which were exposed to different degrees of space weathering even on this small scale. Both nanotips contain small nanophase Fe particles (~3 to 10 nm diameter), with these particles becoming less frequent with depth.

One of the nanotips contains a sequence of space weathering products, compositional zoning, and a void space (~15 nm in diameter) which we interpret as a vesicle generated by solar wind irradiation. No noble gases were detected in this vesicle, although there is evidence for \(^{4}\)He on the edge of this feature. The outermost layer of the grain is more enriched in the minor elements than the nanophase Fe area, suggesting that some of the rim material is sourced from outside of the ilmenite grain and is a true redeposition rim, formed by the condensation of vapor produced by the impact of micrometeorites on adjacent grains and by deposition of materials sputtered by energetic solar wind ions from the nearby grains.

In the other nanotip, H-bearing ionic or molecular species such as OH\(^+\) and H\(_2\)O\(^+\), are present in the greatest amounts at a depth range of 40–50 nm, fully consistent with H\(^+\) solar wind implantation at typical energies (Fig. 1). The outermost layer of space-weathered soil comprised of O-rich minerals, such as that of this ilmenite grain, may be an important source of water on the Moon.
This lunar soil grain exhibits the same space weathering features that have been well documented employing transmission electron microscope (TEM) studies of lunar and Itokawa asteroidal regolith grains. The zones we observe in the lunar material have the same compositional characteristics as material returned from Itokawa [8,9], but have different depth ranges. APT is an ideal analytical method to study nanoscale surface effects of precious samples, such as mission‐returned samples like those presented herein and is a complementary technique to TEM.

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Figure 1. APT concentration profiles (top) of H-bearing ionic or molecular species along the axis normal to the grain’s surface, with a shape consistent with simulated [7] H+ implantation at 4 keV (bottom) into a material with properties comparable to ilmenite [5].
References