AQUEOUS ALTERATION ON THE MOON. F. Vilas[1], D. L. Domingue[2], E. A. Jensen[3], L. A. McFadden[4], C. R. Coombs[5], and W. W. Mendell[1], [1]NASA Johnson Space Center, Planetary Science Branch, Houston TX 77058, [2]The Johns Hopkins University/Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel MD 20723, [3]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA 02139, [4]Department of Astronomy, University of Maryland, College Park MD 20742, [5]Department of Geology, College of Charleston, Charleston SC 29424.

Introduction: One of the more controversial issues concerning lunar science today is the debate over the absence or presence of water at the lunar poles. While it has been postulated that water ice is stable and can exist in the permanently shadowed areas of the lunar poles [1], recent observations show conflicting evidence for the existence of this polar water ice. Clementine's bistatic radar experiment detected a weak signal at the lunar South Pole attributed to water ice [2]. Conversely, ground-based radar observations show no radar signal suggestive of water ice at either pole [3]. Lunar Prospector has recently detected large amounts of H at both poles, also interpreted as indicative of the presence of water ice [4]. However, Galileo near-infrared spectra taken along a 30-km wide swath in the northern polar region did not detect the presence of absorption features due to adsorbed and interlayer H_2O in phyllosilicates [5]. This contradictory evidence leaves the lunar polar water ice issue unresolved. To add fuel to the fire of this debate we provide additional indirect evidence supporting the presence of water-bearing minerals near the lunar South Pole based on analyses of Galileo SSI image photometry.

Analytical Methodology: One spectral identifier of aqueous alteration is a broad absorption feature at 0.7-µm due to an $Fe^{2+} \rightarrow Fe^{3+}$ charge transfer transition in six-fold coordination in oxidized iron. This absorption feature is seen in reflectance spectra of many terrestrial phyllosilicates, CM2 carbonaceous chondrite meteorites, and many low albedo asteroids [6,7,8]. The Galileo Earth-Moon pass 1 LUNMAP14 images (which are the most rigorously calibrated images covering terrain near the lunar South Pole) [9] were examined for evidence of the presence of this absorption feature. This was accomplished by examining spectral slope variations for each pixel in the LUNMAP 14 color images. The spectral slope for the spectral segments between 560-nm and 670-nm, between 670-nm and 756-nm, and between 756-nm and 889-nm were measured from the corresponding filter images and compared. The ranking of the slopes for the different spectral segments flags the presence or absence of absorption features near 0.7-µm and features centered between 0.9-1.0-µm (the M1 mafic silicate absorption feature), while allowing for the presence and magnitude of the "reddened" slope (increasing reflectance with increasing wavelength) in a lunar spectrum. Each pixel flagged with this procedure was visually inspected. This examination method was tested with laboratory measurements of various terrestrial and lunar soil spectra that had been convolved with the Galileo image filter response functions.

Results: The following table lists those craters in the lunar south polar region which have evidence for the presence of phyllosilicates on adjacent walls.

Crater	Longitude (deg)	Latitude (deg)
Gruemberger	11 W	-67
Klaproth	28 W	-70
Clavius	15 W	-49
Drygalski	81W	-78
Zeeman	145 W	-75
Unnamed (SW of Drygalski)	Est. 105 W	Est. -80
Unnamed (ENE of Drygalski)	Est. 65 W	Est. -76
Unnamed (E of Drygalski)	Est. 70 W	Est. -81
DeForest	Est. 157 W	Est. -80

One possible scenario for creating phyllosilicates near the lunar South Pole begins with the implantation of hydrogen atoms from the solar wind into the lunar soil. The hydrogen reacts with iron oxide in the lunar minerals and glasses ($FeO + H_2 \rightarrow Fe + H_2O$) to create minor amounts of water vapor and iron metal [14]. Over most of the Moon the water vapor would quickly sublime from the surface because of the high surface temperatures (5-10% could migrate to any permanently shadowed polar region). However, theoretical studies suggest that temperatures within permanently shadowed regions of polar craters have temperatures low enough for water ice to be stable across the lifetime of the Moon [15]. In addition, a lunar surface at 100K not in shadow will retain water for ~100 years, while such a surface at 50K will retain water for billions of years [15]. At lunar latitudes of $\pm60^\circ$-80° temperatures of $\leq$100K are expected in shaded portions of larger craters. The time scales for aqueous alteration reactions vary, requiring hours to years, depending on temperatures, compositions, and water:rock ratios of the starting materials. Thus, the equatorward (cooler, sometimes shadowed) walls of large, complex craters located near the poles could retain water vapor, liquid or ice for sufficient amounts of time for aqueous alteration to occur. Continuous meteoritic bombardment of the lunar surface provides heat pluses strong enough to melt water and effect the aqueous alteration of some of the anhydrous surface material on small scales. Over the lifetime of the older craters, phyllosilicates in small quantities have been produced at the cooler, equatorward walls of the craters and, through gardening, laterally mixed with the anhydrous silicate surface materials near the crater rim. This is a steady-state process currently operating on the lunar surface.

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