EXAMINING POSSIBLE ENDOGENIC WATER ON THE MOON IN THE NEAR AND MID INFRARED WITH THE LUNAR TRAILBLAZER MISSION. R. L. Klima[1] (Rachel.Klima@jhuapl.edu), B. L. Ehlmann[2,3], D. L. Blaney[3], N. E. Bowles[4] S. Calcutt[4], J. Dickson[2], K. L. Donaldson Hanna[4,5], C. S. Edwards[6], R. Evans[4], R. Green[3], W. Frazier[3], R. Greenberger[2], M. A. House[7], C. Howe[8], J. Miura[2], C. Pieters[9], M. Sampson[10], R. Schindhelm[10], E. Scheller[2], C. Seybold[3], D. R. Thompson[3], J. Troeltzsch[10], T. J. Warren[1], K. Shirley[1], and J. Weinberg[10]. [1]Johns Hopkins Applied Physics Laboratory, Laurel, MD, [2]California Institute of Technology, Pasadena, CA, US, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, US, [4]Department of Physics, University of Oxford, UK, US, [5]Department of Physics, University of Central Florida, Orlando, FL, US, [6]Northern Arizona University, Flagstaff, AZ, US, [7]Pasadena City College, Pasadena, CA, US, [8]STFC RAL Space, Didcot, UK, [9]Brown University, Providence, RI, US, [10]Ball Aerospace & Technologies Corporation, Boulder, CO, US.

Introduction: Recent lunar missions and the advancement of sample analysis techniques have resulted in a wealth of new information about the Moon. The discovery of water/hydroxyl (OH) in and on the Moon [e.g., 1-7] is one of the most surprising and important findings from the last decade, both for science and human exploration. Scientifically, understanding the origin of lunar water/OH provides insight into how planets accrete and evolve thermally, as well as into the nature of surface reactions on a planetary regolith and volatile transport. For exploration, understanding the distribution, volume, and bonding of water/OH guides the development of *in situ* resource technologies and informs landing site selection. Integration of existing orbital and laboratory data is critical for addressing the science and exploration questions and identifying, as a community, what missions or measurements are necessary to answer the outstanding questions. We focus here on localized water/OH anomalies that have been observed from orbit, and efforts to understand whether these are due to endogenic lunar water or other factors.

Background and Motivation: Studies of water/OH in lunar samples suggest a complicated history of water in the lunar interior. Though originally believed to be quite dry, analyses of lunar glasses [e.g., 5-6] and apatites [e.g. 7-8] suggest that at least some reservoirs may contain water at abundances similar to the mantle source of the Mid Ocean-Ridge Basalts on Earth. Because the Moon is mineralogically dominated by anorthite, olivine, and pyroxene, none of which incorporate large amounts of OH^- into their mineral structures, water present in the lunar magma ocean should have been concentrated with other incompatible elements into urKREEP, the liquid that carried the potassium, rare earth element and phosphate (KREEP) geochemical signature measured in many lunar samples. However, the majority of analyses suggest an anticorrelation between the KREEP signature and OH^- abundance [e.g., 8]. This implies not only that the lunar mantle is heterogenous but also that somehow water has been decoupled from other incompatible elements.

While clearly not of the same precision as laboratory data, orbital data can potentially provide additional constraints about the global distribution and diversity of incompatible elements on the Moon. Characterization of absolute OH^- abundance from orbit is complicated by surficial adsorbed OH^-, likely produced by interaction of solar wind hydrogen with minerals on the surface [e.g., 10], as well as a thermal emission component in the same spectral region as OH/H_2O absorption bands.

Localized enhancements in OH/H_2O have been reported corresponding to specific lithologies, including silicic domes, pyroclastic glasses, and deeply-sourced norites and anothosites, and provide tantalizing hints that they could be associated with endogenic OH [e.g., 9-11]. In the case of Bullialdus crater [9] and Compton-Belkovich [10], the enhanced OH^- coincides with relative enhancements in thorium as detected by the Lunar Prospector (in the case of Compton-Belkovich, thorium levels may be the highest on all of the Moon) [12]. These findings suggest that the rocks within Bullialdus crater and Compton Belkovich likely contain a large amount of potassium, rare earth elements, and phosphorus (KREEP) [9-10], contrary to what has been observed in OH^--enriched returned lunar samples.

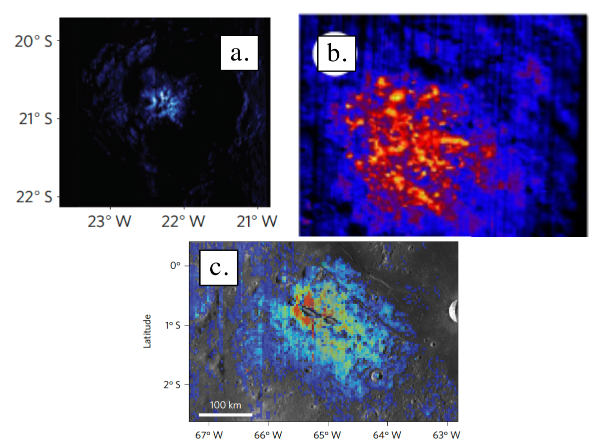

Fig. 1. Examples of water/OH anomalies at the (a) noritic central peak of Bullialdus crater [9], (b) the silicic complex Compton Belkovich (61.1°N 99.5°E) [10], and (c) the Grimaldi pyroclastic deposit [11].

Existing Complications: Different thermal corrections of the M³ data have been attempted to improve our understanding of spatial and temporal distribution of lunar surface water on sunlit terrains, to test how robust our current understanding of water on the surface of the Moon is [14,15,16]. The 3-micrometer cutoff wavelength for M³ results in ambiguities in the strength, shape, and position of the water/OH absorption band. Thermal emission further complicates the data, as the true temperature of the measured surface needs to be subtracted from the signal to quantify the water band depth. While the temperature of the surface can be estimated using observations from the Diviner Lunar Radiometer (Diviner) as a guide, this is not as straightforward as it might seem because the M³ and Diviner instruments did not observe concurrently and both instruments are sensitive to slightly different depths in the lunar epiregolith. Discrepancies resulting from different thermal modeling techniques and assumptions about surface roughness, lead to conflicting results about whether some anomalies represent real differences in water/OH abundance or are simply artifacts due to the nature of the lunar surface [16]. Without further measurements, these discrepancies are likely to remain contentious and unresolved for the foreseeable future.

The Lunar Trailblazer Instruments: NASA recently selected the SIMPLEx smallsat Lunar Trailblazer [17], which will carry the High-resolution Volatiles and Minerals Moon Mapper (HVM³; 0.6-3.6 µm, similar to M³ but explicitly designed to focus on water measurements) [18], as well as the Lunar Thermal Mapper (LTM) [19], a thermal infrared multispectral imager to directly and simultaneously measure the temperature and rock type within each HVM³ pixel.

The measurements collected by Lunar Trailblazer will improve upon existing data in several ways. The HVM³ instrument [18] is designed explicitly to examine both the shape and distribution of water absorption bands in targeted regions. The higher (~70 m/pixel rather than ≥140 m/pixel) spatial sampling improves the ability of HVM³ to map the boundaries of water/OH anomalies, while the nominally 20-km-wide swaths still provide critical spatial context to allow data to be georeferenced with analyzed in the context of existing lunar data sets. The 10-nm spectral sampling and longer spectral range allows the form of water/OH to be characterized, as well as the thermal contribution from the surface to be directly removed by modeling the continuum of the near-IR data. The shorter-wavelength range of HVM³ retains sensitivity to mafic minerals, ensuring that the lithology of the rock hosting the water signature can be clearly interpreted.

Simultaneous measurements taken by the LTM [19] provide an independent, direct measurement of the surface temperature, as well as a measurement of surface roughness within the HVM³ pixel at a spatial sampling of ~18-34 m/pixel. Narrow filters, positioned in the region of the Christiansen Feature (CF), ensure that in addition to temperature and other thermal properties, LTM can provide an independent measure of the composition of the targets measured, with enhanced spectral resolution relative to Diviner for characterizing silicate composition, particularly of olivine-rich and plagioclase-rich lithologies.

The Lunar Trailblazer Mission: As a low cost smallsat mission, Lunar Trailblazer is designed to perform focused, targeted science to resolve specific science questions, including the question of whether water/OH is preferentially associated with certain lithologies, latitudes or soil maturities and whether the abundance of water/OH is time variable. At proposal, the baseline selected mission plan was to collect ~1000 20x20 km image cubes of targets that have been selected to follow up on lunar water discoveries of the last decade. However, a trade is underway to determine what the cost would be to ensure that the spacecraft had the potential to support global imaging of the Moon. Given the current push to return to, and remain on, the lunar surface, this science enhancement option would provide the capability to perform detailed compositional mapping from orbit of potential landing sites, complementing the existing data from LRO and other instruments.

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