GLOBAL DISTRIBUTION OF LUNAR SILICATES FROM THE DIVINER LUNAR RADIOMETER. B.T. Greenhagen[1], P.G. Lucey[2], T.D. Glotch[3], J.L. Bandfield[4], C.C. Allen[5], N.E. Bowles[6], I.R. Thomas[6], M.B. Wyatt[7], K.L. Donaldson Hanna[7], and D.A. Paige[8], [1]Jet Propulsion Laboratory, 4800 Oak Grove Drive, M/S 183-301, Pasadena, CA, USA Benjamin.T.Greenhagen@jpl.nasa.gov; [2]University of Hawaii, Honolulu, HI, USA; [3]Stoney Brook University, Stoney Brook, NY, USA; [4]University of Washington, Seattle, USA; [5]Johnson Space Center, Houston, TX, USA; [6]University of Oxford, Oxford, UK; [7]Brown University, Providence, RI, USA; [8]University of California, Los Angeles, CA, USA.

Introduction: The Diviner lunar radiometer has made the first direct global measurement of silicate mineralogy of the lunar surface using multispectral thermal emission mapping. The Diviner compositional investigation primarily relies on the three narrowband thermal infrared channels near 8 μm. Observed variations between maria and highland regions establish a baseline for the determination of new compositional constraints. Using Diviner data, we have discovered areas featuring spectra consistent with unusual lunar lithologies (specifically high silica and/or non-anorthite plagioclase composition) and found a significant lack of kilometer scale exposures of olivine-rich lunar mantle.

Diviner Lunar Radiometer: Launched onboard the Lunar Reconnaissance Orbiter in June 2009, Diviner is a nine channel pushbroom mapping radiometer designed to measure broadband reflected solar radiation (two channels) and emitted thermal infrared radiation (seven channels) between 0.3 and 400 μm [1]. The three shortest wavelength thermal infrared channels (ch 3: 7.55-8.05 μm; ch 4: 8.10-8.40 μm; ch 5: 8.38-8.68 μm – referred to herein as the "8 μm channels") were specifically designed to measure the Christiansen feature (CF) [2], which is directly related to silicate mineralogy of lunar soils in the lunar environment [e.g. 3,4]. Diviner's longer wavelength thermal infrared channels span the mid- to far-infrared between 13 and 400 μm. Despite their broadness, observed differences between these channels easily allow separation of feldspar-rich highland areas and ultramafic lunar maria and we use these parameters as additional constraints on composition.

Christiansen Feature: In the lunar environment (characterized by a fine particulate surface and vacuum resulting in high thermal gradients), the CF has significantly enhanced spectral contrast compared to other mid-infrared features (Figure 1). The CF occurs when the refractive index (real part) of a material approaches the refractive index of the surrounding medium AND absorption is relatively low ($n \approx 1$, $k \approx 0$). The CF is tied to the fundamental vibrational band and shifts to shorter wavelengths with increasing polymerization of the SiO_4 tetrahedra (e.g. framework silicates exhibit CFs at shorter wavelengths than less polymerized pyroxene and olivine).

Identifying the CF. Diviner's 8-μm channels span the CF locations of lunar soils measured in simulated lunar environments reported in the literature, 7.95 to 8.50 μm [e.g. 5]. The CF location is determined by solving the quadratic formula for the three 8 μm channels ($y = A x^2 + B x + C$). A parabola closely approximates the shape of the CF when measured in the lunar environment. For most Diviner observations, the parabola is concave down ($A < 0$) and the CF location is taken to be the wavelength of the parabola's maximum. However, when the actual CF is sufficiently far from the 8 μm channels (e.g. quartz, albite, etc.), it may appear concave up ($A > 0$), reflecting the fact that the Christiansen feature does not occur within Diviner's channel range.

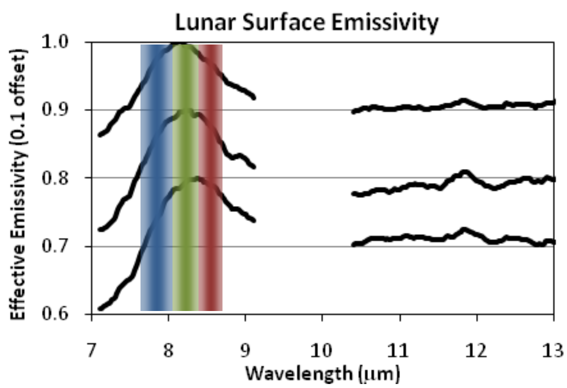

Figure 1: Diviner 8 μm channels and the CF. The approximate positions of the 8 μm channels (ch 3: blue, ch 4: green, ch 5: red) are superimposed over balloon-borne telescopic thermal emission observations at 32 km altitude with 300 km circular spot size: (A) Copernicus, (B) Central Highlands, (C) Mare Serenetatis [Data from 6]. The CF located near 8 μm dominates mid-infrared thermal emission.

Diviner Global Silicate Mineralogy: Diviner data clearly show compositional differences related to lunar maria and highlands. Figure 2 is a global CF map using three months of Diviner data (late August through mid November), representing late morning through early afternoon local lunar time. The range of *typical*

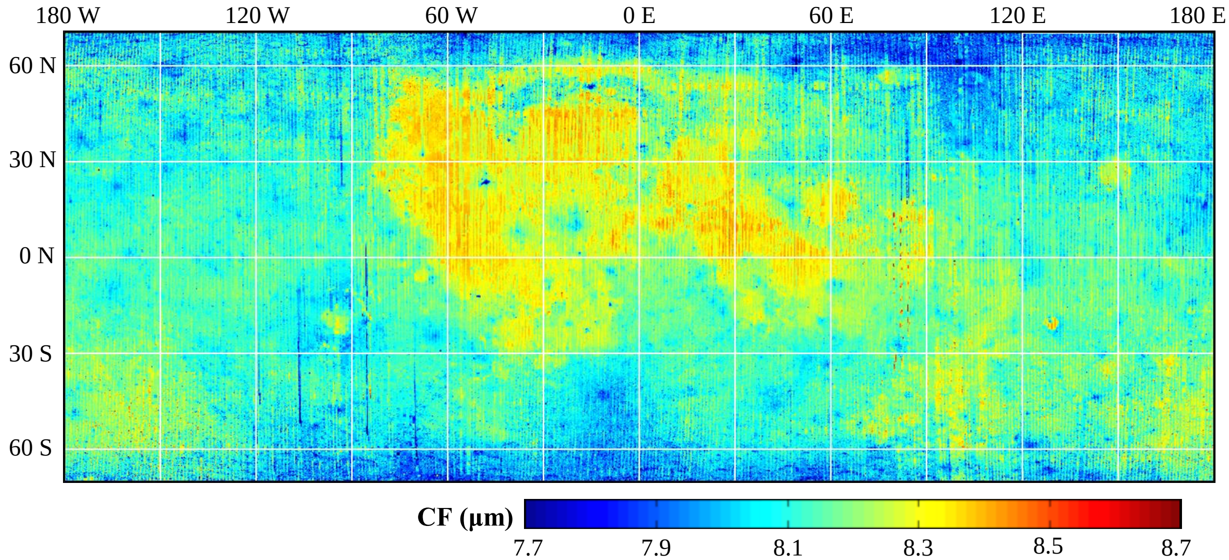

Figure 2: Global Christiansen Feature Map. Highland regions are blue to cyan-green. Mare regions are green orange. Dark blue regions have CFs shorter than anorthite. If present, red to dark red would indicate high olivine composition. Diviner compositional maps reveal interesting structure in both maria and highlands. This map was created using Diviner data empirically corrected for latitudinal and time-of-day CF observation bias.

CFs observed by Diviner is 8.01 to 8.37 µm. Lunar maria and highland areas have modal CFs of 8.29 and 8.15 µm respectively, although there is significant variability due primarily to plagioclase abundance. These CF values are consistent with the work of Murcray and coworkers [6], lunar regional observations, and laboratory measurements of lunar soils in a simulated lunar environment [e.g. 5]. Our observations of Apollo sites suggest compositions similar to returned soils [7]. Apollo 16 has the highest plagioclase abundance and shortest wavelength CF (8.13 µm). Apollo 11 appears the most mafic (8.36 µm CF).

Unusual lithologies. Although most Diviner CF observations fall near the range of typical highlands and maria, Diviner is directly sensitive to and can put tight constraints on, compositions with unusual CF locations and signatures. These compositions include quartz, high-Si glass, and potasic/sodic feldspars with CF locations at shorter wavelengths than typical highlands, and olivine, with locations longer than typical mare. Indeed Glotch and coworkers [8] have shown that some lunar "red spots" exhibit unusual concave up signature associated with CF locations well short of the 8-µm channel range that are consistent with high silica content. Additionally, some areas previously identified as pure plagioclase [9] appear to have CFs short of anorthite indicating the presence of a potasic/sodic feldspar component. Finally, although Diviner is extremely sensitive to the presence of olivine (which has an unusually high CF value), there is little evidence for km scale outcrops of high olivine concentration.

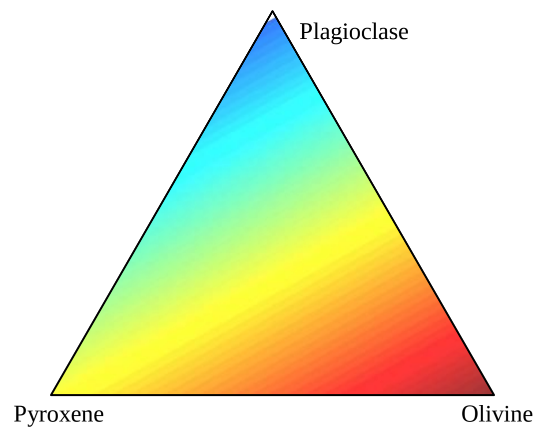

Figure 3: Notional CF Ternary. This figure is a schematic that approximates the relationship between composition and the color scale in Figure 2 above.

Summary: It is clear that in addition to providing constraints lunar surface composition Diviner data have significant potential for discovery. Using Diviner data we have found exposures of unusual lunar lithologies and a lack of olivine-rich lunar mantle materials.

References: [1] Paige D.A. et al. (2009) *SSR*, online. [2] Greenhagen (2009) Ph.D. Dissertation, UCLA. [3] Logan L.M. et al. (1973) *JGR*, *78*, 4983-5003. [4] Nash D.B. et al. (1993) *JGR.*, *98*, 23535- 23552. [5] Salisbury J.W. et al. (1973) *LPS IV*, 3191- 3196. [6] Murcray F.H. et al. (1970) *JGR.*, *75*, 2662-2669. [7] Allen C.C. et al. (2010) *LPS XLI*. [8] Glotch T.D. et al. (2010) *LPS XLI*. [9] Ohtake M. et al (2009) *Nature*, *461*, 236-240.