REMOTE SENSING ASSESSMENT OF LUNAR RESOURCES: WE KNOW WHERE TO GO TO FIND WHAT WE NEED

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The utilization of space resources is necessary to not only foster the growth of human activities in space, but is essential to the President's vision of a "sustained and affordable human and robotic program to explore the solar system and beyond." The distribution of resources will shape planning permanent settlements by affecting decisions about where to locate a settlement. Mapping the location of such resources, however, is not the limiting factor in selecting a site for a lunar base. It is indecision about which resources to use that leaves the location uncertain [1]. A wealth of remotely sensed data exists that can be used to identify targets for future detailed exploration. Thus, the future of space resource utilization predominately rests upon developing a strategy for resource exploration and efficient methods of extraction.

The Clementine [2] and Lunar Prospector [3] missions have provided global datasets that already provide the distribution of many potential lunar resources. Clementine acquired multispectral images from ultraviolet through near-infrared wavelengths. These data allow assessments of the abundances of major minerals (plagioclase, pyroxene, ilmenite, and olivine) on the Moon [4]. In addition, the data can be used to determine the FeO and TiO_2 contents of the surface to ~1wt% accuracy and high spatial resolution [5-8]. The distribution of pyroclastic materials with their enrichments of FeO and TiO_2 and possible volatile elements are mapped using Clementine multispectral data and derived optical maturity data [9]. Perhaps even more important, ^{3}He can be mapped by association with TiO_2 and surface maturity [10]. The abundance of ^{3}He in the lunar regolith depends on surface maturity, the amount of solar wind flux, and titanium content. Clementine bi-static radar data provided initial evidence that water-ice exists in permanently-shadowed regions near the poles.

Mission	Measurements
Apollo ~100-150 km/pixel	Gamma-ray and X-ray data Th, K, Mg, Si, Al
Clementine (0.415, 0.75, 0.9, 0.95, 1.0, 1.1, 1.25, 1.5, 2.0, 2.6, and 2.7 μm) ~200 m/pixel	Multispectral images: FeO and TiO_2 Mineralogy/Pyroclastics Optical Maturity ^{3}He
Lunar Prospector 15-150 km/pixel	Gamma-ray and Neutron data Fe, Ti, Th, K, H, Sm, Gd
Earth-based observations 2-5 km/pixel (spectra) 400 m/pixel (radar)	Visible to near infrared spectra Mineralogy/Pyroclastics Radar Backscatter Maturity Opaque abundance Ice

Lunar Prospector gamma-ray and neutron spectrometers determine the concentrations of Fe, Ti, Th, K, H, Sm, and Gd [8, 11, 12]. Fe and Ti data provide an independent check on the concentrations determined by reflectance spectroscopy [6]. Neutron spectrometer data indicate the presence of hydrogen deposits at the lunar poles, which if present as water-ice suggests a H_2O concentration of 1-2 wt% [13].

Earth-base radar observations (70 cm) also have a sensitivity to bulk FeO and TiO_2 abundance. The correlation of abrupt changes in radar return with color boundaries in Clementine color and TiO_2 images indicates that the data are controlled, to a significant degree, by the TiO_2 (ilmenite) composition of the regolith [14]. The greater depth of penetration of radar data compared to the Clementine data (several meters versus microns) will allows the assay of TiO_2 abundance to greater depth. Earth-based radar does not, however, concur with Clementine concerning the existence of ice at the south pole of the Moon [15]. This apparent discrepancy in the presence of ice has not been satisfactory explained, and will require closer study by orbiting and landed missions

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