
Remote geochemical mapping of lunar impact melt associated with complex craters is a key to better understanding of impact melt formation and the impact cratering process. Ground-based NIR spectra and Clementine multispectral images comprise a dataset with high-resolution spectral and spatial information, respectively. To interpret these data with respect to impact melt, two suites of lunar samples are being measured in NASA's Reflectance Experiment Laboratory (RELAB) at Brown University. The samples include seven Apollo 17 crystalline impact melts as well as synthesized glass equivalents, and 11 naturally occurring impact glasses from several landing sites. Acquisition and analysis of the laboratory spectra is the first step towards quantitatively modeling remote spectra to learn more about the composition and source of the melt found at complex craters. Furthermore, from the laboratory spectra, basic compositional parameters may be determined for application to Clementine data. Initial measurements of the Apollo 17 melt rocks have been completed and are presented below.

Background: Impact melt is commonly observed in and around lunar complex craters, where it appears to have splashed or flowed, and often ponded before cooling (e.g., 1, 2). Remote geochemical mapping of these units is a key to understanding more about the formation of impact melt, and about the impact cratering process as a whole. Visible and near infrared remote sensing data (in the form of high resolution spectra and multispectral images) is currently the most widely available type of lunar data. The empirical and theoretical basis for such mapping, however, must be further developed before compositionally-based mapping is possible.

Near infrared telescopic point spectra for three craters (Copernicus, Tycho, and Aristillus) indicate that despite different geologic settings and locations, the melt rocks are extremely similar spectrally (3). They appear to have significant amounts of Fe-bearing glass mixed with lithic fragments and/or recrystallized melt. Determination of the relative abundance of glass and crystalline material at these and other locations associated with complex craters is an important step towards understanding the formation and behavior of melt during an impact. Mapping the spatial distribution of melt is also important, serving the dual purpose of providing more information about the crater formation process, and of distinguishing between melt rocks and exposed or uplifted rocks related to pre-impact stratigraphy. In Clementine multispectral images, known areas of impact melt are distinguished by a strong "red" continuum slope and low albedo, but these spectral characteristics are non-unique. Further investigation is required to determine appropriate spectral parameters that unambiguously identify impact melt. It should be noted that purely crystalline melt rocks may be spectrally indistinguishable from volcanic or plutonic rocks. Unlike the glass-bearing, apparently quenched melts at craters such as Copernicus or Tycho, therefore, basin-related impact melt (in the form of slowly cooling sheets) may not be readily distinguished remotely.

Approach: Systematic laboratory measurements of lunar impact melt samples are necessary to identify the diagnostic properties of lunar impact melt. As a first step in acquiring and analyzing sufficient laboratory data to develop a quantitative model, two suites of lunar samples are being measured in RELAB. One suite consists of naturally occurring glassy melts, representing a range of compositions and Apollo landing sites. The other suite consists of Apollo 17 melt breccias, which are being measured as powders of both the original crystalline material and of glass beads made from each sample (see Table 1). The glass beads are prepared by fusion on Mo strips in an argon atmosphere, and are then ground to <125 μm powders. (The samples are part of a separate effort by (5) to characterize the compositional homogeneity of the Serenitatis melt sheet. Six of the seven samples are inferred to be from the Serenitatis impact, but nonetheless span a range in composition and grain-size/texture. The seventh sample is distinct in petrography, chemistry, and inferred origin.) They were selected for the RELAB study because they have spectral properties and chemical and petrographic characteristics that can be directly compared, and because the glass versions of the samples are reasonable simulants of quenched impact melt glass. Each sample has been measured independently, and will also be measured in a series of mass fraction mixtures. The naturally occurring glass samples will also be measured, and the reflectance spectra and compositional data will ultimately be used to constrain quantitative models such as the MGM (6).

Preliminary Results: The crystalline melt spectra (Figure 1) are indicative of lunar rock powders that vary mainly in the relative abundance of pyroxene and plagioclase. The strength and position of the absorption bands near 1 and 2 μm are related to pyroxene composition and abundance, while the albedo is related to the abundance of feldspar and opaques as well as grain and particle size. The weak feature near 0.6 μm which appears in some of the spectra may be due to the presence of small amounts of fine-grain ilmenite suspended in a non-opaque silicate matrix. The feature near 1.2 microns appears to be correlated to the 0.6 micron band, although it is by itself generally associated with plagioclase. The glass spectra (Figure 2) vary less with composition. The glass beads appear identical in hand sample, and the powders are green in color, as manifested by the strong reflectance peaks near 0.56 μm. The broad absorption bands centered just beyond 1 μm and 1.9 μm, due to crystal field transitions of Fe2+ in octahedral and tetrahedral coordination respectively, are diagnostic for glass. The strength of these bands...
depends upon the amount of iron present, while the UV/VIS absorption is due to charge transfer between Fe and Ti (4). In Figure 3, the spectra have been convolved through Clementine filters and the 415/750 nm ratio is plotted against albedo at 750 nm. Because of the small range in FeO and TiO2 abundance, these samples represent a small subset of melt compositions expected on the Moon. However, they illustrate the more limited variability among the glasses (homogenous melts of similar chemistry) relative to their crystalline counterparts. Furthermore, while each melt is redder than its crystalline parent, albedo variations are unpredictable and mixtures would be non-unique in this plot. Further work with mass fraction mixtures and more variable compositions should set detectability limits of glass and lithic fragments in remote spectra, and increase the confidence with which such melts are identified in multispectral imagery.

Table 1

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