PRELIMINARY STUDY OF LUNAR SEPARATE PRODUCTION FROM STILLWATER DEPOSITS

Jackie Graham[1], Danielle Granlund[1] and Courtney Young[2]. Department of Metallurgical and Materials Engineering, 208 ELC, Building, Montana Tech, 1300 W. Park Street, Butte, MT. [1]Student, jngraham@mtech.edu and dagranlund@mtech.edu. [2]Dept Head and Prater Professor, cyoung@mtech.edu.

Introduction: In order to colonize the Moon, we must determine if and how lunar soil can be used for construction, will interact with equipment and clothes, can grow trees and plants, will affect human and animal health, and can be beneficiated to yield mineral and metal commodities necessary for long-term habituation. Unfortunately, the Apollo missions did not bring back enough samples to study and characterize fully. Studies emphasized making and characterizing "simulants" such as Minnesota Lunar Simulants (MLS-1 and 2) and Johnson Space Center (JSC-1, 1A, 1F, 2 and 3). When international simulants were developed including several from Japan (FJS-1 and MKS-1) and China (CAS-1), a new moon race developed.

Most of these simulants were made from single resources of terrestrial igneous rock, predominantly from volcanic areas, with a focus on the elemental content and not the mineralogy and chemistry. To make the simulants, these volcanic materials were mixed with fluxes, heated to a molten state, allowed to solidify, and, after cooling, crushed, ground and pulverized to a size consistent with lunar soil. Consequently, these thermally-produced simulants do not accurately and adequately mimic lunar soil. McCay and Blacic (1991) claimed "Simulants of lunar (rocks and) soils with appropriate properties, although difficult to produce in some cases, will be essential to meeting the system requirements for lunar exploration."

Lunar Soil Mineralogy: Over 95% of Lunar Soil is comprised of silicates belonging to four groups: Orthopyroxene [$(Mg,Fe,Ca)(Mg,Fe,Al)Si_2O_6$], Clinopyroxene [$(Ca,Na)(Mg,Fe)(Si,Al)_2O_6$], Ca-rich Plagioclase [$(Ca,Na)(Si,Al)_4O_8$] and Olivine [$(Mg,Fe)_2SiO_4$]. The remaining 5% is composed of over 100 other minerals, mostly oxides in minor amounts, including rutile (TiO_2), ilmenite ($FeTiO_3$) and chromite ($FeCr_2O_4$).

Objective: At question is whether a terrestrial resource could be exploited to produce a simulant. An exploratory study was therefore undertaken at Montana Tech as an undergraduate research project.

Approach: To meet this objective, the following steps were deemed best to take:

- Find at least one appropriate terrestrial resource that contains the lunar minerals.
- Characterize the resources according to their mineral and chemical content.
- Identify differences in physical and chemical properties so that unit operations can be examined to concentrate and purify the lunar minerals into individual "separates."
- Test the unit operations to develop a flowsheet to produce the mineral separates.
- Produce and mix the separates in the appropriate ratios to match the content of the lunar soil.

Making simulant in this manner would allow impurities to be removed from the individual separates thereby allowing many terrestrial resources to be considered. Furthermore, the mineral separates would allow bulk processing of rocks to make high grade feed stocks for later grinding and mixing. Larger quantities of simulant would therefore be produced faster. In addition, tremendous savings in time, labor and costs would be realized because the thermal processes currently used to produce simulant would be avoided.

Following discussions with NASA and USGS geologists, this study focused on making separates of the four major silicate minerals. It was further noted that, in order to further keep expenses to a minimum, deposits from mine sites should be explored such that a new mine would not need to be established. Focus was therefore given to the deposits at and near Stillwater Mining Company's Nye Mine near Columus, MT.

Procedures: Various analytical tools were used to characterize the Stillwater deposit including a Scanning Electron Microscope/Mineral Liberation Analyzer (SEM/MLA), X-Ray Diffractometer (XRD) and X-Ray Fluorometer (XRF). Likewise, numerous process equipments were used to make separates. These included magnetic separators (dry rolls, WHIMS, and wet drums all equipped with either rare earth or electro magnets), high-tension dry roll separators, gravity separators (shaking table, spiral, and Knelson concentrator), chemical separators by batch flotation, and chemical convertors by leaching and ion exchange (column, bottle roll, agitation, autoclave and titration).

Conclusions: Although the four major lunar minerals are silicates that are normally discarded as tailings in typical mineral beneficiation operations, results indicate that simulant production from separates is viable.