MAGNETIC BENEFICIATION OF HI-TI MARE SOILS: CONCENTRATIONS OF ILMENITE AND OTHER COMPONENTS*. **Lawrence A. TAYLOR,** Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996; **Robin R. ODER,** EXPORTech Company Inc., New Kensington, PA 15068.

In order to prepare for the establishment of a lunar outpost, it is prudent to begin the study of utilization of lunar resources now. The most readily accessable resource on the Moon is its soil. This can be used in bulk as insulation against cosmic and solar rays, for lunar ceramics and abodes, and for growing plants. However, beneficiation of the soil can provide other feedstocks. For example, the soil contains useful solar-wind implanted elements, notably hydrogen and helium, agglutinates for the recovery of native Fe, glassy components with valuable volatiles and refractory materials, as well as various minerals for sources of such metals as Fe, Co, Ni, Al, Si, and Ti [1]. Logical processes of beneficiation include sizing, magnetic, electro- static, and density separations. The most important components are: 1) **ilmenite,** feedstock for the extraction of O_2, H_2, ^3He, Fe, and Ti; 2) **agglutinates** for Fe and volatiles; 3) **volcanic glass** for volatiles; and 4) **selected minerals** (e.g., anorthite) for extraction of O_2, Al, Fe, etc.

Mare basalt soils possess the greatest potential for resource utilization. The present study examines 3 **high-Ti mare soils,** representing various maturities — **71061 (Immature;** I_s/FeO = 14); **71501 (Submature;** I_s/FeO = 35); **10084 (Mature;** I_s/FeO = 78). The soil samples were sieved into size fractions of >150, >74<150, >40<74, >20<40, and <20 um. These were each magnetically separated into various susceptability modes. Each of these splits was characterized by particle counts and bulk chemistry. This report emphasizes the rock, mineral, and glass components of the soil.

A Frantz Isodynamic Separator, instrumented for both separations and magnetization measurements, was employed [2-4]. A polished grain mount was prepared from 5-10 mg portion of each magnetic split from the size fractions. Individual particles were identified using both relected- and transmitted-light microscopy. A population of about 300-700 grains was sought for each polished section. Another 5-10 mg portion, as well as bulk splits from each size fraction, was fused in dry nitrogen using a Mo-strip heater. The resulting glasses were mounted in epoxy and polished; numerous electron microprobe analyses were performed upon each glass sample.

Particle Analysis - The classification of a soil grain is subjective. In this study, modified criteria were employed in order to bring out otherwise masked subtleties. For example, although a fragment might properly be classified as a basalt, if it contained >40 modal % ilmenite, it was classified as "Ilmenite". Thus, it is not possible to quantitatively model the proportion of specific particles which are free of other attached phases — i.e., monomineralic. As grain size decreases, however, degree of liberation of phases becomes more complete. The results of the particle counts for each magnetic split from the various size fractions are summarized in Fig. 1.

Soil Components - The dominant lithic fragments observed in the 3 mare soils studied are **Coarse- and Fine-grained Basalts** (50-200 um vs. 5-75 um), and typically contain 10-20 modal % ilmenite. In the Basalts, many of the ilmenite grains contain appreciable armalcolite [$(Fe,Mg)Ti_2O_5$]. Based upon the large grain size of some of the ilmenite, pyroxene, and plagioclase (400-600 um), it is probable that a very coarse-grained basalt was also originally present. Highland grains (i.e., >80% plagioclase) were identified as **ANT** (Anorthosite-Norite-Troctolite). **Microbreccia,** with the presence of mineral and lithic clasts in a predominantly crystalline matrix, and volcanic-like **Glass** beads and fragments are particularly abundant in the mature soil, 10084.

The fused soil fragments consist of **Agglutinates, Melt Rock,** and **Impact Glass;** the last two are combined for graphical purposes. The Melt Rock fragments appear similar to the Agglutinates but have no vesicles. Also, the decrease in agglutinates with decrease in grain size is caused by the loss of identity, resulting from fractionation into subcomponents (e.g., impact glass, melt rock, lithic fragments, minerals). The particles classified as minerals consist of **Plagioclase, Pyroxene/Olivine** (mostly clinopyroxene), **Ilmenite,** and **Native Fe,** including minor amounts of troilite (FeS).

ILMENITE: Ilmenite concentrates in intermediate Magnetic Susceptibilities (MS's) for all three of the soils; free Ilmenite particles have an MS of 60-160 micro cc/gm. Although a relative enriched (i.e., 30%) ilmenite fraction can be obtained by sizing (>20<44 um) and magnetic separation for sample 10084, this consists of less than 20% of the total soil sample. From examination of polished sections, it appears that the majority of the ilmenite is present in coarse-grained basalts in >74 micron fractions. It would seem that grinding of the >74 um fraction of the soil would further liberate additional ilmenite. **Ilmenite modal % decreases with the maturity of a soil;** the **"normative" ilmenite >> modal ilmenite.** This is to be expected as the impact melts consume additional minerals and rocks. We observe that Immature to Submature soils (e.g., 71061, 71501) are better for ilmenite separation than a Mature soil (e.g., 10084).

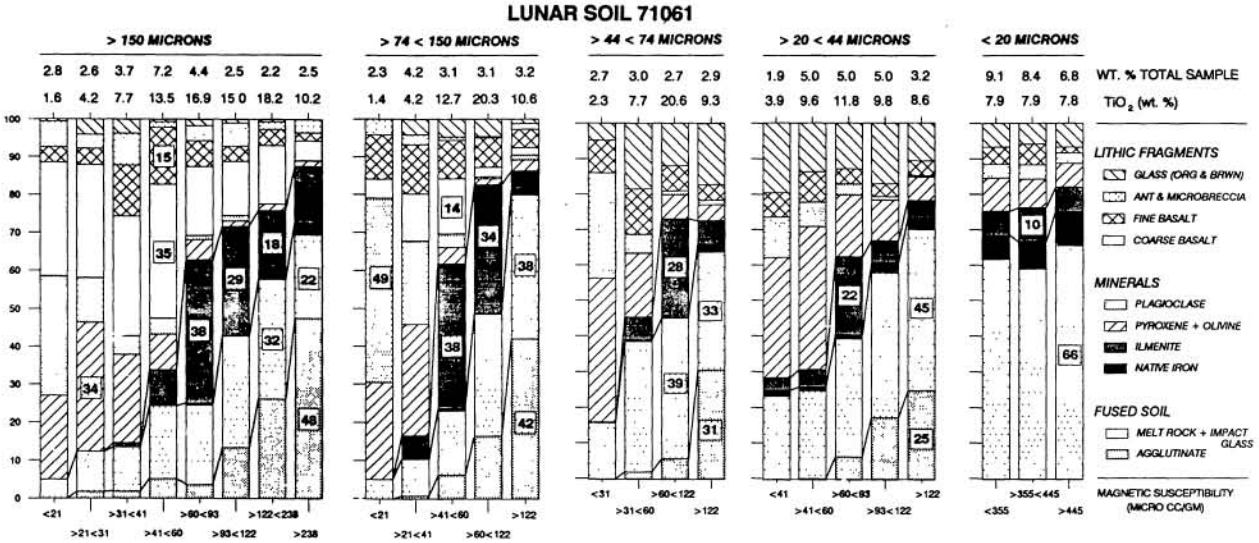
AGGLUTINATES: Agglutinates are typically concentrated in the highest MS fraction, a function of their abundant "single-domain Fe" [5]; agglutinates with highest MS have the greatest amount of glass. Melt Rocks are concentrated in the intermediate to high MS fractions, with more free native Fe as the MS increases; Agglutinates + Melt Rocks = 90^+ % in the 44-74, 74-150, and >150 um of the mature soil 10084;

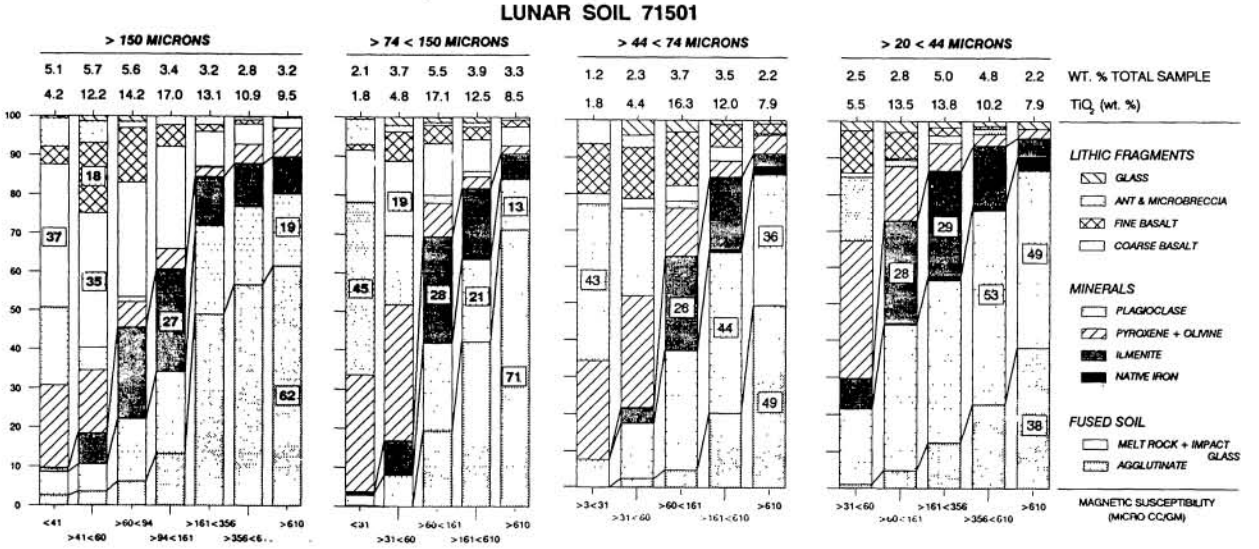
NATIVE FE: Grains of Native Fe are concentrated (10^+%) in the <20 um fraction (30% in 10084). Ferromagnetic Native Fe is most abundant in the highest MS fraction.

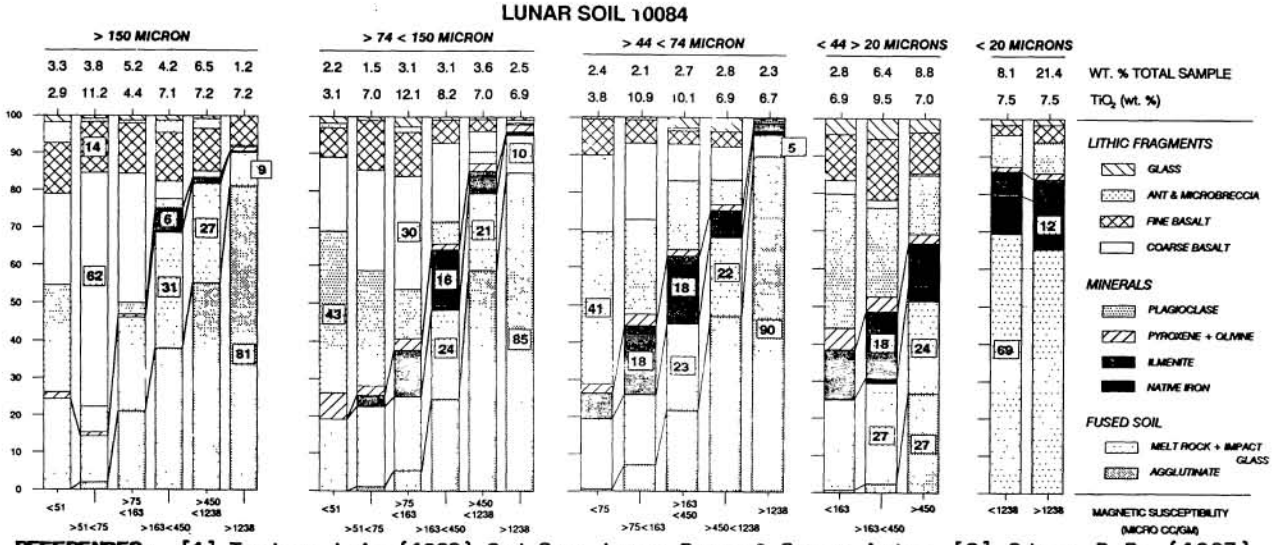
ORANGE & BROWN GLASS: These glasses are concentrated in the 44-74 um, and, to a lesser extent, in the 20-44 um size fractions; Orange Glass is concentrated in lower MS, brown in higher MS.

* Supported by NASA Contract No. NAS 9-18092.

BENEFICIATION OF HI-TI MARE SOILS - TAYLOR, L.A. & ODER, R.R.







REFERENCES: [1] Taylor, L.A. (1990) 2nd Sym. Lunar Bases & Space Act.; [2] Oder, R.R. (1987) Proc. 4th Pittsburgh Coal Conf.; [3] Oder, Taylor, & Keller (1989) LPSC XX, LPI; [4] Oder, Taylor, & Keller (1989) Space Studies Inst. Conf.; [5] Taylor, L.A. (1988) Space 88, ASCE.