Lunar Regolith

Figure 54 – Footprint in lunar soil. Few rocks are sitting out on top of mature regolith. NASA photo AS11-40-5877.

The lunar surface is covered by a layer of unconsolidated debris called the lunar regolith (fig. 53). The thickness of the regolith varies from about 5 m on mare surfaces to about 10 m on highland surfaces. The bulk of the regolith is a fine gray soil with a density of about 1.5 g/cm^3, but the regolith also includes breccia and rock fragments from the local bedrock (reviews by Heiken *et al.* 1974 and Papike *et al.* 1982). About half the weight of a lunar soil is less than 60 to 80 microns in size. The grain size distribution is given in figure 55.

Since the Moon lacks any sort of an atmosphere, the upper few millimeters of the regolith is exposed to the bombardment of micrometeorites and to solar wind irradiation. The extensive bombardment by micrometeorites, which continues today, breaks up soil particles and melts portions of the soil. The melt, mixed with lithic fragments, forms irregular clusters called agglutinates (fig. 56). At the same time, the solar wind implants large quantities of H and He and trace amounts of other elements. Continued reworking by micrometeorites of the hydrogen-enriched soil particles causes melting, and the reaction of H with FeO forms H_20 vapor and submicroscopic metallic Fe grains in the resulting agglutinate glass. This process continues until the surface layer is buried by fresh ejecta or is broken up by a large crater. Trenches and core tubes into the regolith reveal that it is stratified with many buried soil horizons. The maturity of a regolith sample is the integrated exposure that it had to the micrometeorite and solar wind environment. Maturity is variously measured by the agglutinate content, grain size distribution, and/or the amount of implanted solar wind rare gases. However, the easiest way to measure maturity has proven to be by magnetic determination of the amount of submicroscopic iron (Morris 1978).

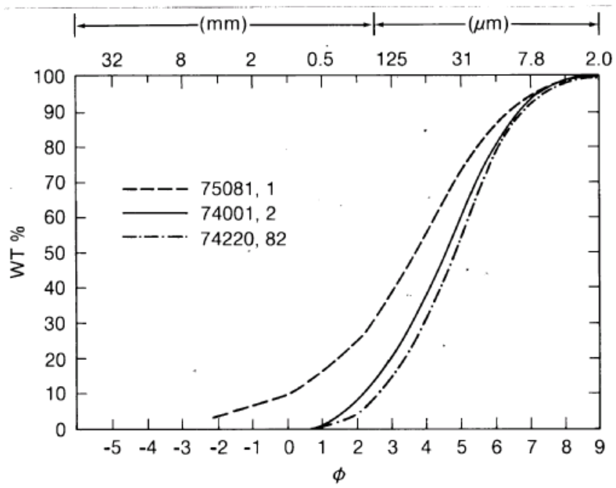

Figure 55 - Grain size distribution of mature lunar soil (75081) and orange soil (74220). About 10 percent of a lunar soil is greater than 1 mm, 50 percent is greater than 100 microns, and 90 percent is greater than 10 microns (from Heiken *et al.* 1974).

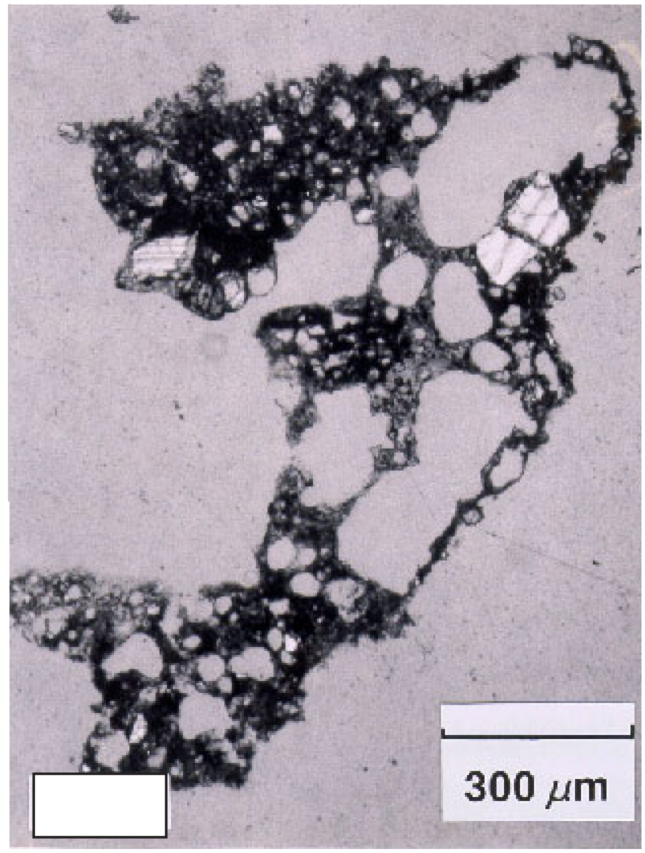

Figure 56 - Thin section photo of a lunar agglutinate. Vesicular glass welds soil particles together. Minute Fe particles are present in the glass.

The rays of Moon craters are evidence that small particles can travel great distances on the Moon. Glass and lithic fragments in the lunar soil are of great interest, because they provide clues of the nature rocks derived from well beyond the sampling site. For this reason, lunar scientists have shown great interest in the coarse-fine fraction of the lunar soil. Coarse-fines are the sand size particles in the lunar regolith. This thin section set includes 1-2 mm and 2-4 mm coarse-fines from both a highland and a mare site. The coarse-fines include glasses, locally derived and exotic lithic fragments, microbreccias, and agglutinate particles.

The astronauts found few rock samples to pick up on mature regolith surfaces. The rocks had all been comminuted to fine soil, by the micrometeorite bombardment over the past billion years. Sampling strategy dictated that rocks be returned from the rims of fresh craters that had punched through the regolith (fig. 57). However, small meter-size craters into the lunar regolith cause breccias to form from the regolith itself. Many of the hand samples returned from the Apollo 11 and 15 sites were regolith breccias. Lunar breccia 15299 (included in this set) is thought to be a regolith breccia, because it has the magnetic properties of a submature lunar soil.

Finally, the lunar regolith also can include a percentage of pyroclastic material. Although no recognizable volcanic glass was found at the Apollo 16 site, a great deal of volcanic glass was found at the Apollo 15 and 17 sites (Delano and Livi 1981). Be sure to look for evidence of green glass in sample 15299 and of orange glass in the Apollo 17 soil samples. Volcanic glass has also been reported in the Apollo 11 soil breccias. How do you distinguish volcanic glass from glass made by meteorite bombardment?

Figure 57 - Meter-size craters in the lunar regolith are capable of producing soil breccias like 15299. Many were lined with glass in the bottom. Fresh craters 10 m and larger are required to dig up hand specimens from the bedrock. NASA photo no. AS12-47-6939