LUNAR SAMPLE COMPENDIUM. C. Meyer, KT, Astromaterials Research Exploration Science, NASA Johnson Space Center, Houston TX 77058 (charles.meyer-1@nasa.gov)

The Lunar Sample Compendium is a succinct summary of what has been learned from the study of Apollo and Luna samples of the Moon. Basic information is compiled, sample-by-sample, in the form of an advanced catalog in order to provide a basic description of each sample. Information presented is carefully attributed to the original source publication, thus the Compendium also serves as a ready access to the now vast scientific literature pertaining to lunar samples. The Compendium can be found online using Google. Alternatively, it can be found at the curator's web site http://www-curator.jsc.nasa.gov.

It has been said that the Apollo lunar sample collection is "*a gift that keeps on giving*." The initial allocations of lunar samples were done sparingly, because it was realized that scientific techniques would improve over the years – which they have. In addition, new questions about the origin and evolution of the moon were formulated and it is no surprise that requests for lunar samples by scientists continue to the present day in order to make new and improved measurements. In general, more than half of most lunar samples are still unanalyzed and available for scientific study. However, the advisory committees are ever mindful of the need to continue to preserve samples for future generations of imaginative scientists. The Lunar Sample Compendium is important because it enables scientists to select samples within the context of the work that has already been done and facilitates better review of proposed allocations. It also provides back up material for review papers and public displays, and it captures some information found only in abstracts, grey literature and curatorial databases.

Lunar samples have been cataloged twice before (1). The initial observations by the Preliminary Examination Teams (PET), along with mug shots of the samples, were recorded in the first set of mission catalogs within months of the samples' return to Earth. Rock samples were recataloged in the 1980s and early 1990s with in-depth descriptions based on detailed scientific study. However, early catalogs were not in color and many samples have now been cut open, revealing the interior texture. Many thousands of petrographic thin sections are now available. Soil catalogs, prepared in 1974 and 1983, haven't been updated since, and the core catalog dates to 1976. As new lunar core tubes were dissected, information was provided only in newsletters to PIs.

In spite of heroic coordination efforts by early advisory committees, and many workshops, there remain gaps and inconsistancy in data and descriptions of many samples. These discrepancies are apparent, once one brings existing data together in summary form. Most samples have been analyzed for most elements. An exception is that additional analyses of highly siderophile elements are needed. These are found in minute amounts, such that analytical difficulties have only recently been overcome. Another apparent problem is that no consistent breccia nomenclature has been followed. Breccia samples range from ancient regolith breccias, to coherent impact melt rocks, to fragmental basin ejecta deposits, to impact bombs from far away, to locally derived, friable regolith breccias.

For some key samples, geochronologic age data are not found to be concordant. Also, over the past 40 years, the decay constants used in age dating techniques have been better determined. Instead of making corrections, the Compendium currently presents the original data, leaving it up to the user to apply the appropriate correction. New decay schemes, such as Lu-Hf, and micoanalytic techniques, such as Pb/Pb ion probe, are now yielding new age data. Many issues are involved.

Several high quality reviews have been presented, where samples are grouped together and conclusions drawn (2, 3). For A14, A16 and A17 the USGS reviewed sample data in context of their field relations (4). These reviews do an excellent job of summarizing the data in the context of scientific problems.

The Lunar Sample Compendium is divided into sections on basalts, breccias, plutonic samples, regolith (soils, cores, trenches and ancient breccia), oriented samples for studies of Solar Cosmic Ray interaction, public display samples and support for the lunar educational thin section teaching collection (5). The Lunar Sample Compendium includes,

- brief petrographic description (inc. significant clasts in breccias),
- complete chemical composition and plots,
- radiometric age data (uncorrected),
- cosmic ray and solar wind exposure,
- physical properties (magnetic, electrical, reflectance spectra),
- processing (subdivision, public display),
- detailed individual bibliographies,
- and a comprehensive bibliography.

In general, it has been learned that the mineralogy of lunar samples is rather simple, with only a few major minerals (plagioclase, pyroxene, olivine and ilmenite). The rocks formed in a completely dry and very reducing environment, such that the iron is mostly in a plus two oxidation state with minor metallic iron. Grain boundaries between minerals are remarkably distinct, with no alteration products. Glass is present in the mesostasis. Minerals that might have been added by meteorite bombardment have generally been vaporized.

There are a few unique features in lunar rocks; plagioclase is almost pure anorthite, maskelynite is common, rare ternary feldspar (Na, K and Ca) is found. Pyroxene has a wide range of composition, somewhat characteristic of each rock type. New minerals include armalcolite, tranquillite, pyroxferroite, and yttrobetafite. Akaganeite (FeOOH) was found on one Apollo 16 breccia. ZnS coatings were found on volcanic glass beads.

The surfaces of lunar rocks that were exposed to space have a thin brown patina of glass splashes and glass-lined micrometeorite craters (zap pits). Solar flare tracks are abundant beneath these surfaces. Depth profiles of cosmic ray induced radio-nuclides extend to depths of 10 cm.

Basalts from lava flows were sampled in abundance. Although fresh in appearance, they measured to be quite old – 3.2 to 3.9 b.y. There are 134 samples of basalt greater than 40 grams, 42 greater than 500 grams, 24 greater than one kilogram, 11 greater than two kilograms and the largest 9.6 kilograms (15555). They have textures of a crystallized liquid – ranging from variolitic to subophitic to equilgranular. Most are fine-grained with an average about 0.5 mm, but some have phenocrysts over one cm. Most of the lunar basalts are Fe-rich, often Ti-rich, and have abundant opaque minerals. Some are very vesicular, with interconnecting vugs and vesicles (15016). A few lunar basalts are greatly enriched in rare-earth-elements (14310, 15382, 15386). All true basalts were found to have low siderophile (Ni, Ir and Au) content.

Lunar breccias are the lithified aggregates of clastic debris and melt generated by meteorite bombardment in the ancient lunar highlands (~3.9 b.y. ago). There are 59 lunar breccias larger than 500 grams, 39 greater than one kilogram and 19 greater than two kilograms. Many of the breccia samples are ejecta from the giant basin-forming events. Others are interpreted as melt sheets from the fallback of hot ejecta into the large lunar basins. Some have a fragmental matrix made up individual mineral fragments, while others have a crystalline matrix from slow cooling of initially molten matrix. A few lunar breccias are soil breccias containing glass beads and a component of solar wind. Most breccia samples are polymict, containing a wide variety of clasts, which are themselves breccias of an earlier generation. Key to the understanding of soils and breccias are measurement of otherwise trace element gold and iridium (which indicate the amount of admixed meteoritic material). Breccia clasts with low levels of gold or iridium are termed “pristine”, meaning they haven’t been contaminated by meteoritic materials and must be remnant pieces of the original lunar crust. Using trace siderophile and volatile element signatures, some scientists have even assigned breccias to specific lunar craters!

There are many regolith samples (over 160 soils, 10 trenches, 20 drive tubes and 4 deep drill cores). Photographs of the sawn surface of epoxy-impregnated cores reveal the texture of the regolith. Perhaps the most important samples are the comprehensive samples, where rake samples, cores, and trench samples were collected along with large surface samples. A brief section on the USSR Luna regolith samples is included.

The Lunar Sample Compendium is a work in progress (*and may always be*). Future plans include: adding sections on additional samples, adding new thin section photomicrographs, replacing the faded photographs with newly digitized photos from the original negatives, attempting to correct the age data using modern decay constants, adding references to each section, and adding an internal search engine. The Lunar Sample Compendium is in digital format (.pdf) and allows broad distribution via the internet. Each file is short so that it can be rapidly downloaded. It is being presented online, even as it is being developed. As of 2009, it is incomplete with only about 250 out of 2000 samples completed (many in draft form). However, it includes many of the more ‘well studied’ samples. A superior Lunar Meteorite Compendium is also on line (6).

References: (1) http://www-curator.jsc.nasa.gov (2) Heiken, Vaniman, French, Lunar Sourcebook, Cambridge (3) Jolliff, Wieczorek, Shearer, Neal, New Views of the Moon, Reviews Min. & Geochem. 60, MSA (4) USGS Prof Papers 880 (1977), 1048 (1981) and 1080 (1981). (5) Meyer, Lunar Educational Petrographic Thin Section Set. NASA JSC (6) Righter, Lunar Meteorite Compendium.