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N89-18290

HOW SUCCESSFUL WERE THE LUNAR SAMPLING TOOLS?: IMPLICATIONS FOR SAMPLING MARS; J. H. Allton & C. B. Dardano, Lockheed EMSCO, P.O. Box 58561, HOUSTON,TX. 77358

Like the Mars Sample Return endeavor, the Apollo lunar-sample program began with definition of strategy for sample collection and of scientific requirements for sampling hardware design. A review of the pre-mission recommendations as they influenced hardware design and compared with the samples obtained and actually used may be helpful. Influential and detailed pre-mission criteria resulted from two mid-1960's summer studies involving the scientific community (1,2). Pre-mission strategy and requirements followed through the actual allocation of samples will be restricted to the Geology and Geochemistry Groups, since these groups remain interested in lunar samples today. The Geology Working Group was interested in characterizing the material underlying the plains and in the processes responsible for the fine structure of the surface. A more global view was taken by the Geochemistry Group, whose list of scientific inquiries included: comparing the chemical and isotopic composition of the Earth and Moon, comparing the time scale for lunar events to those established for Earth history, determining lunar evolution by establishing relative ages of major lunar events, establishing the Moon as a primitive or differentiated body, determining the gross composition of the lunar surface as a whole, establishing the relative roles played by internal and external processes in shaping present topography, and finally, surveying the Moon's resources such as water, oxygen, and energy (1).

In seeking answers to these questions, the following strategies were devised. The highest priority was to return some sample from each landing site. To assure some kind of sample return, a "grab" or "contingency" sampling procedure was proposed. If given time to make selections, samples from dust to rocks in size and from surface and subsurface were desired. Numerous small samples were preferred over fewer larger samples. Fragments of a few centimeters diameter were considered adequate for petrographic studies. Astronauts were encouraged to use judgement in sample selection and to try and obtain at least one of each type, including exotic samples. A statistical or grid method was considered very poor strategy. Samples collected and returned were to be free from chemical contaminants, some were to be aseptic, and some were to be maintained under lunar environmental conditions.

The Geology Group specified the types of hand tools needed for sample collection. They viewed sampling as a very precise operation requiring the astronaut to have "down on the hands and knees" flexibility and regarded documentation as extremely important. On the other hand, The Geochemistry Group viewed the sampling process more broadly, as the gathering of a variety of samples under very clean conditions. Consequently, they defined which materials would be acceptable for touching lunar samples.

Specific hand tools under development in early 1967 included 3 core tubes, 3 aseptic sample collectors, scriber-hand lens-brush, tongs, 200 sample bags, scoop, hammer, and a bio-science sample collector (3). Drive tubes were thought to be useful for obtaining samples representing an entire profile from greater depths than would be possible with a trench. A 3-meter drill was planned for later missions. Suggestions for sample containers ranged from hermetically sealable teflon bags (biological barriers) to rigid containers capable of maintaining the lunar environment. Requirements for the Apollo Lunar Sample Return Container (ALSRC) included retention of 10^{-6} torr vacuum, retention of interior temperatures less than 65 °C, and construction of stainless steel (preferred) or aluminum.

Materials for hand tools and containers were recommended to minimize or eliminate contamination from Pb, U, Th, Li, Be, B, K, Rb, Sr, noble gases, rare earths, micro-organisms, and organic compounds. The main structural materials were aluminum alloy 6061 and 300 series stainless steel. Teflon was the only acceptable plastic, although Viton was acceptable for backup, exterior seals. MoS_2 was agreed upon for a lubricant, as was use of soft indium metal for sealing surfaces.

The lunar surface hand tools used to collect samples on the Moon and the types of samples each tool collected are given in Table 1. Curatorial data for sample types, roughly corresponding to those in Table 1, are shown in Figure 1. For each sample type, the total number of sub-samples allocated for scientific research, the average weight of the samples (as collected on the Moon), and the number of sub-samples allocated per gram of collected sample are displayed. The large number of allocations indicates that the lunar samples were studied intensively. The number of sub -samples allocated per gram of collected sample indicates relative scientific interest in different sample types. A larger number of smaller, more specific samples were taken on later missions; hence, the Apollo 15-17 data are set apart from Apollo 11-14 data in the chart. The rake sample rocks (taken only on Apollo 15-17) were compiled separately from rocks which were selected individually to see what effects random selection had on sample usefulness. The rake smaller sample size influences the "interest index" more than the selection process. Increased petrologic variability per unit weight attracted greater scientific "interest" as exhibited by the small fragments extracted from soils (these 1 to 10 mm size fragments were extracted in the laboratory from bulk soils). "Interest" in cores is enhanced, because they possess the added variability of depth. Yet, 8 core tubes remain unopened, because cores did not fulfill the expectations of definitive stratigraphy.

Several lessons can be illustrated by specific tools. The evolution of drive tubes from narrow 2-cm diameter, thick-walled tubes (used on Apollo 11, 12 and 14) to 4-cm diameter, thin-walled tubes used on Apollo 15, 16 and 17) is an example of the improvements made possible during multiple missions. The original Apollo 11 drive tube was designed to work in fluffy soil; thus, only 50% of the relatively dense lunar soil was recovered, and the core was distorted (4). The final configuration resulted in nearly 100% recovery with little distortion (5). The surface samplers (Contact Soil Sampling Devices) were designed to collect the upper 100 μm or the upper 1 mm of soil. It was over 2 years after the mission before these particularly specific samplers were opened because interest in them waned. Both core tubes and surface samplers were difficult to open in the laboratory. The ALSRC's were constructed with one indium and 2 Viton seals. They were closed on the lunar surface. Interior container pressures measured upon return to the laboratory (Table 2) indicate that these seals were not reliable in the lunar environment. Also, choice of indium as a sealing material interfered with siderophile analyses of samples.

Conclusions about sampling devices: unreliable container seals, the need to redesign the drive tubes, and difficulty in opening samplers suggest that 1) Mars sampling strategy be viable if seals fail, 2) tools be simple (drill corer necessary?), and 3) the curation environment (low P, low T, zero-G ?) be defined early so that laboratory handling can be a design requirement.

Conclusions about sample types: good use of small samples, intensive use of 1-10 mm soil fragments, lack of apparent core stratigraphy, and non-use of some cores indicate that 1) numerous small samples be collected, 2) fragments be concentrated by sieving soils, 3) sampling strategy be viable if core stratigraphy is not apparent, and 4) core samples be examined on the Martian surface to determine science value.

Table 1. HAND TOOLS USED TO COLLECT LUNAR SAMPLES

TOOLS	TYPE SAMPLE COLLECTED	MISSION
Contingency sampler	Surface soil & small rocks	11, 12, (14-17?)
Tongs	Particular rocks with shortest dimension <6 cm	All
Large scoop	Surface soil & small rocks	11, 12
Adjustable scoop	Surface & subsurface soil	12 - 17
Adjustable trenching tool (shovel)	Subsurface soil	12 - 17
Hammer	Pieces of large rocks, drive the core tubes	All
2-cm drive tubes	.5 m soil column	11, 12, 14
4-cm drive tubes	.5 m soil column	15, 16, 17
Drill	3 m soil column	15, 16, 17
Rake	Statistical sampling of fragments >1 cm	15, 16, 17
Surface samplers	Upper 100 um & upper 1mm of soil	16
Astronauts	Big rocks	All

Table 2. APOLLO LUNAR SURFACE RETURN CONTAINER PRESSURES MEASURED IN LABORATORY

MSN	S/N	PRESSURE (atmospheres)
11	1003	.0002
	1004	.0002 (7)
12	S	.00007
	D	.5 (8)
14	1006	.00008
	1007	1
15	1011	.00005
	1012	1
16	1009	1
	1010	.0001
17	1007	.0002
	1006	.00004 (9)

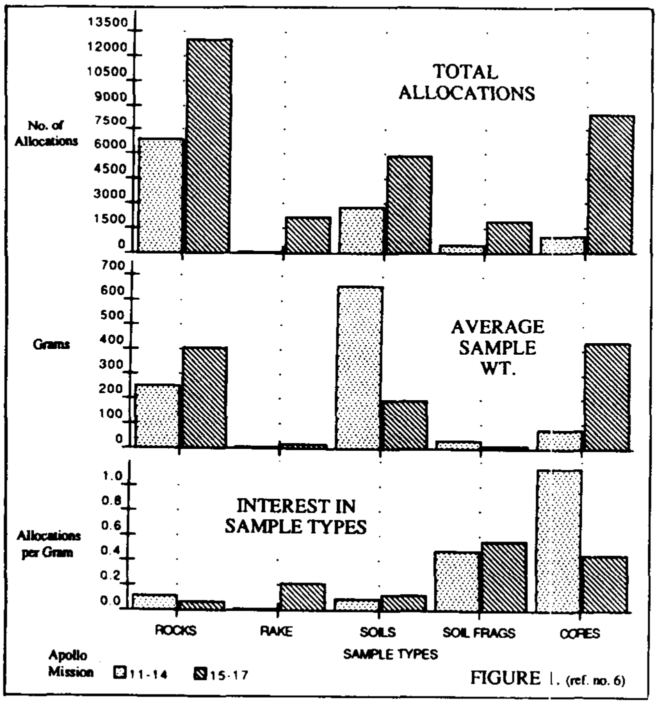

FIGURE 1. (ref. no. 6)

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