VI. The Lunar Samples

The lunar samples were on board the U.S.S. *Hornet*, and we were eager to get additional information on the quantity and types of samples. The crew had been very busy while on the Moon and had not been too talkative about matters that would help us prepare for sample processing and preliminary examination. We decided to send a message to the *Hornet:*

MSC HOUSTON TEXAS — PRIORITY — UNCLASSIFIED

Answers to the first six questions are required prior to arrival of the samples. Please ask the crew the following questions.

1. Approximate amount of fine-sized sample material in documented (second) box
2. Ratio of rocks to fine-sized material in bulk (first) box

3. What is the estimated number of rocks in the documented box?
4. Approximate number of different rock types collected?
5. Are there any samples that appear friable or weakly coherent? If so, approximately how many?
6. Did any samples show color or albedo differences that will enable us to tell tops from bottoms?

Also, please ensure that the documented sample box (second box collected) returns on the first aircraft.

Richard S. Johnston, Special Assistant to the Director
Elbert A. King, Jr., Curator
July 24, 1969, 3:50 p.m.

Their reply came promptly:

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1. Very little, pretty much hard rock
2. Approximately 60 percent fine-sized material
3. Twenty rocks in sample, average one earth pound
4. Approximately six rock types
5. Somewhere packed, doubtful if still in rock form
6. Some lighter on top and darker on bottom

With great euphoria we set up tools and containers in the high vacuum glove chamber accordingly. Arrival at the LRL of the lunar samples was only hours away.

We had taken great precautions to ensure the safety and integrity of the lunar samples once they arrived on Earth. Besides the quarantine precautions, the rock boxes were placed in crash-proof boxes. At 05:15 Greenwich mean time, July 25, an aircraft carrying the documented sample box was launched from the *Hornet*. It was bound for Johnston Island, where another long-range aircraft would carry the box to Houston. Six hours and 30 minutes later, the *Hornet* launched another aircraft transporting the bulk sample box toward Hickam Air Force Base, Hawaii, with the same final destination for the samples.

Someone made a bad joke that it would be a shame if the samples got almost to the LRL but never made it. How could this happen? Maybe a radical group of "hippies" would use the occasion to draw attention to their cause by mounting a demonstration or protest involving the samples. It was the sixties. All kinds of crazy things were happening. Students burned flags and blew up computers. Under the circumstances, I felt extremely paranoid. Only a weak link connected the chain of sample security beginning with the landing of the samples at Ellington. Once the samples were on the base they would most likely be safe. However, a long stretch of Old Galveston Highway and NASA Road One left the samples vulnerable to sabotage before arriving at the space center. I decided the only prudent thing to do was to personally escort the samples. I went home and dropped six fresh rounds into the cylinder of my long-barreled Smith & Wesson .357 magnum, wrapped it in a bath towel, and stuck it under the front seat of my '63 Plymouth Valiant. Of course, probably nothing would happen, but if it did, someone would quickly know I meant business.

The first aircraft carrying the documented sample box landed (with one engine out!) at Ellington more or less on time. I parked where I could see everything on the edge of the runway and watched the transfer of the rock box container from the aircraft to a NASA vehicle (Photo 48). As I imagined, the scene was disorganized and uncontrolled. I followed as the NASA vehicle pulled away and stayed closely behind all the way to the space center. A couple of other cars, one of which was driven by a NASA security officer I knew, jockeyed for position in the column. The NASA security man honked and waved me off. I just honked back, waved, and smiled. The trip from Ellington to MSC proved uneventful, and the documented rock box was admitted to the LRL. The bulk sample box arrived seven hours later. The long-awaited lunar samples were "in the bag!"

A lengthy procedure was necessary in order to move the first rock box into the high vacuum glove chamber where it would be opened. The anticipation was intense. We believed a glimpse of the samples would reveal before our eyes the hidden secrets of the Moon. Four science observer members of the Preliminary Examination Team (PET) waited at their stations on the vacuum chamber when the lid of the documented sample box was popped open. Frondel and I were together on the glove operator's side of the vacuum chamber, and two colleagues shared the other side. After the packing mesh was pulled aside and the foil from the solar wind experiment was moved out of the way, the glove operator came out of the gloves and stepped back, allowing us our first view of rocks from the moon. The sight was unimpressive. Dark lunar dust cov-

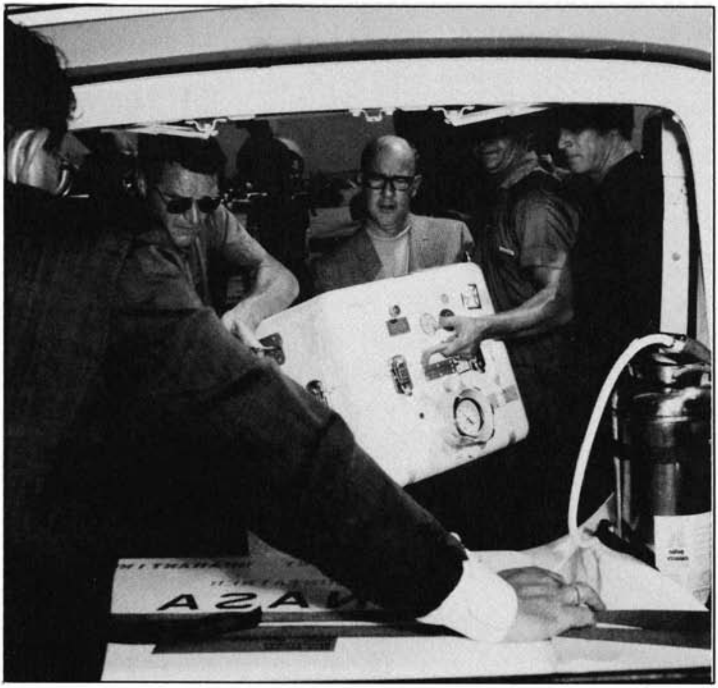

Photo 48. The first lunar rock box from the Apollo 11 mission arrives at Ellington Air Force Base, Houston, in its protective container and is loaded into a NASA vehicle for the short trip to the Lunar Receiving Laboratory. (NASA Photograph S-69-39967)

ered every rock so the true nature of the materials was not visible. One of our colleagues on the far side of the chamber said he could see a light-colored phenocryst (a crystal of larger size than the general matrix of the sample) in one of the samples—almost certainly feldspar and probably plagioclase. From our side of the chamber we could tell it was a flake of the alumina thermal coating from the outside of the box that had fallen on the rock when we opened the lid. We motioned over the top of the chamber for them to "cool it!"

The moment was truly history, but there was little we could observe or say.[22] We counted the rocks and described the size and shape of each piece, but they looked like lumps of charcoal in the bottom of a backyard barbecue grill. The pervasive dark lunar dust obscured everything for the time being.

Frondel became fascinated with the dark, opaque dust. He postulated the dust might be high in carbon, an idea Urey liked a great deal. Frondel stated this hypothesis at a press conference, but cautioned that his conjecture still had to be verified by analysis. His idea turned out to be incorrect.

The MQF, with the crew inside, arrived on July 28. The crew egressed into the LRL Crew Reception Area, which was spacious compared to the MQF. At least here the crew could enjoy some recreation, such as movies and reading material. I had left 10 years of back issues of *Playboy* magazine in the small library, each issue marked "Courtesy of your friendly neighborhood curator."

On July 30, the Command Module was delivered to the LRL, where it was scavenged for lunar dust after the quarantine period.

I participated in one of the technical debriefings of the crew, which took place across the biological barrier in a special room of the LRL Crew Reception Area (Photo 49). The crew seemed rested and happy, and we were all grinning from ear to ear. Little of scientific importance was gleaned from the debriefing. The science story was locked in the rocks, and we had plenty of those.

The rocks were individually cleaned and dusted, inside plastic

[22]For another account of the events of this time, see S. F. Cooper, Jr., *Moon Rocks* (New York: Dial Press, 1970).

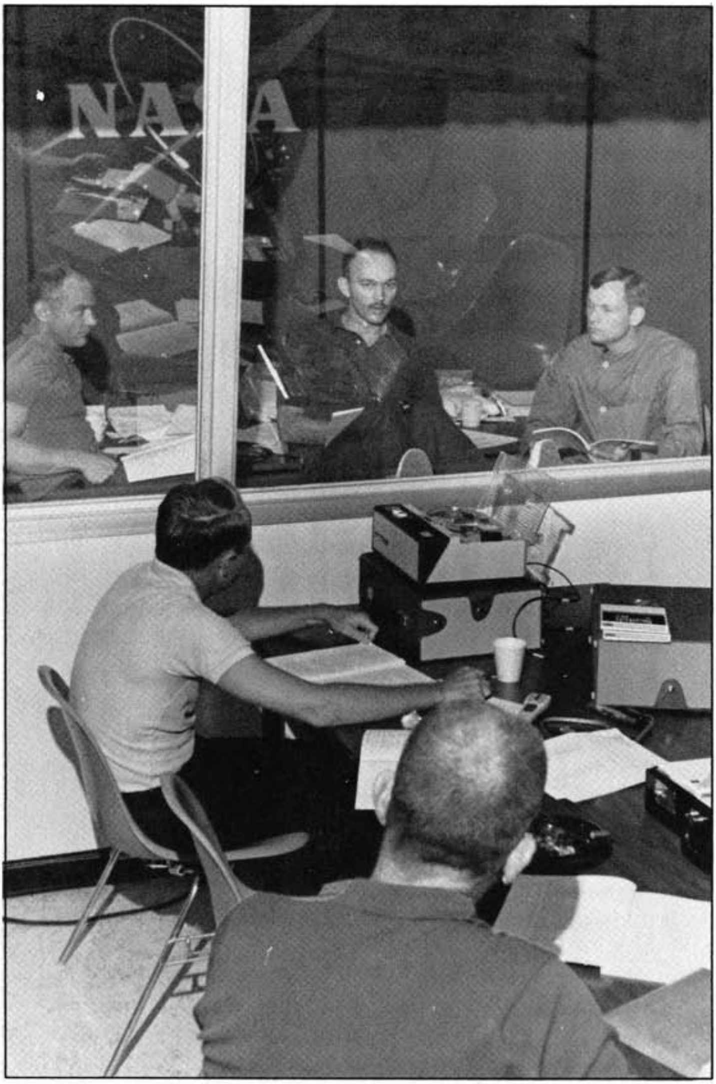

Photo 49. The Apollo 11 crew of (left to right) Buzz Aldrin, Mike Collins, and Neil Armstrong at their first post-flight debriefing in the Lunar Receiving Laboratory. The crew are isolated on one side of a biological barrier and the debriefing team on the other. Deke Slayton (foreground) and Lloyd Reeder (training coordinator) are shown on this side of the barrier. (NASA photograph S-69-40216)

bags in order to avoid losing any dust particles. Their true nature quickly became apparent (Photo 50). The large rocks were of two types. There were ordinary-looking fine-grained volcanic igneous rocks that appeared as fresh as if they had been erupted only yesterday. Also, there were breccias composed of many rock clasts and fine material that had somehow become lithified from crumbly to hard rocks (Photo 51). We hesitated to identify by eye the minerals

Photo 50. Fine-grained lunar basalt with numerous vesicles or gas bubbles collected on the Apollo 11 mission. (Sample 10022, NASA photograph S-69-45524)

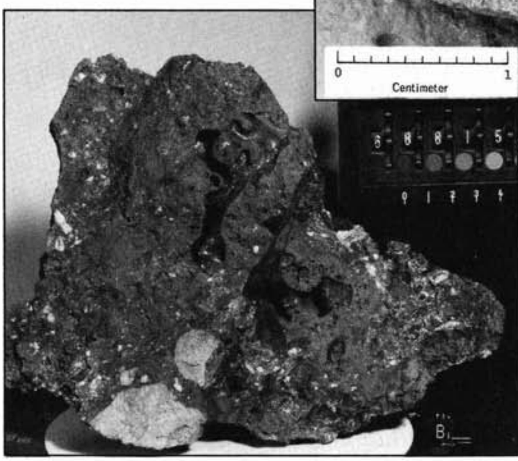

Photo 51. Glassy impact melt-breccia collected at the Apollo 16 landing site. This rock consists of many fragments with different grain sizes and textures held together by glassy material formed by meteoroid impact. Scale (right) is in centimeters. (NASA photograph S-72-37155)

in the igneous rocks because, as one PET member put it, "Remember, these rocks are from the Moon!" Observations were particularly difficult in the vacuum system (Photo 52) since the lighting was poor, the samples commonly were dusty, and there was little space

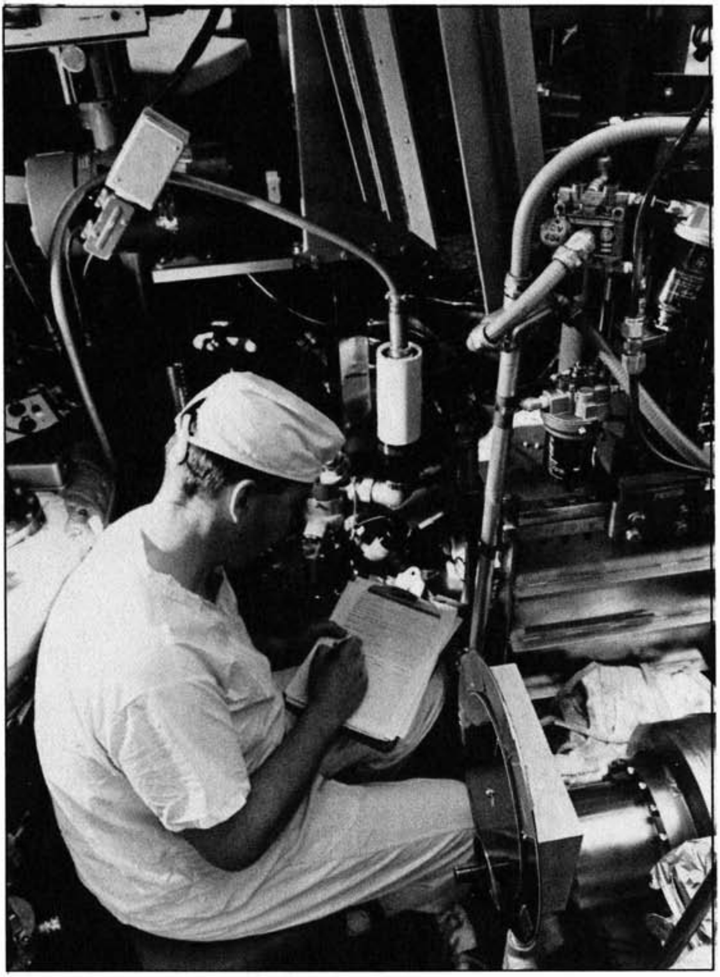

Photo 52. The author noting observations on an Apollo 11 rock sample at the main observer's port on the main vacuum system where the lunar samples were first opened. (NASA photograph S-69-29689)

for an observer. As each shift of PET came off duty, we discussed the new observations with LSAPT.

A curious feature observed on the first crystalline rock we examined was the presence of small glass-lined pits (Photo 53). The members of the PET generally agreed the pits were glass-lined micrometeoritic impact craters because the glass had splashed out over the rims. When this observation was reported to the Lunar Sample Analysis Planning Team (LSAPT) at the end of the shift, Shoemaker took strong exception to the interpretation and suggested the glass-lined cavities probably were vesicles or gas bubbles and would probably be found inside the rocks as well when samples were split. After all, there were no experimentally produced micrometeorite craters with glass linings. Discussion centered over the possibility that lunar microcraters might be produced by higher velocity meteoroids than the experimental ones, but Shoemaker was adamant. Soon we found the craters (which became informally known as "zap pits") on breccias and, of course, did not

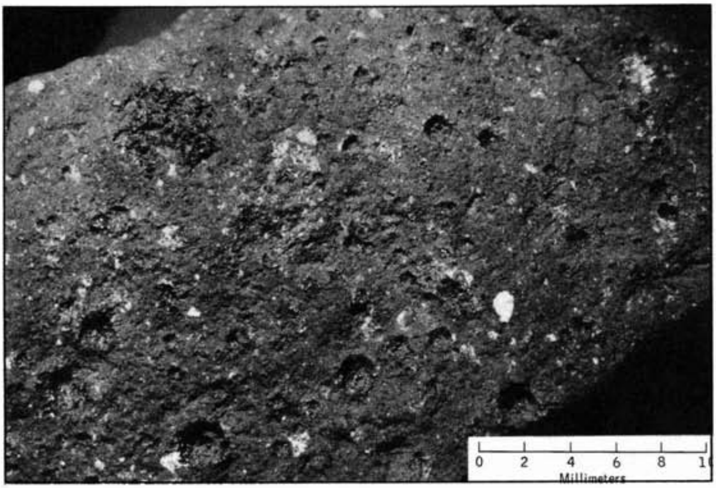

Photo 53. Apollo 11 breccia sample 10019, showing its surface with abundant micrometeoroid impact craters or "zap pits." These small glass-lined craters are abundant on many rocks from the lunar surface. (NASA photograph S-69-47905)

find them in the interiors of igneous samples. Shoemaker had to yield the point. Soon, our colleagues who had made experimental meteoroid impacts were making microcraters with glassy linings.

Chips were taken from a number of samples and passed to the Physical-Chemical Test Lab for the initial mineralogy, petrology, and geochemistry analysis and also to the Biological Test Labs for quarantine evaluation. We were especially pleased that no apparent sample reaction occurred with the dry nitrogen in the glove boxes. The PET, working slowly and moving cautiously, took a long time to derive a single positive mineral identification. We thought we had olivine, calcic plagioclase, and a pyroxene, but we had trouble working through the two-way barrier. The results were coming out very slowly (Photo 54). We opted to sterilize a small sample and work with it outside the biological barrier. I mounted a small yellow-green grain on a fiber and aligned it in an X-ray diffraction camera. A few hours later, analysis showed a pretty good

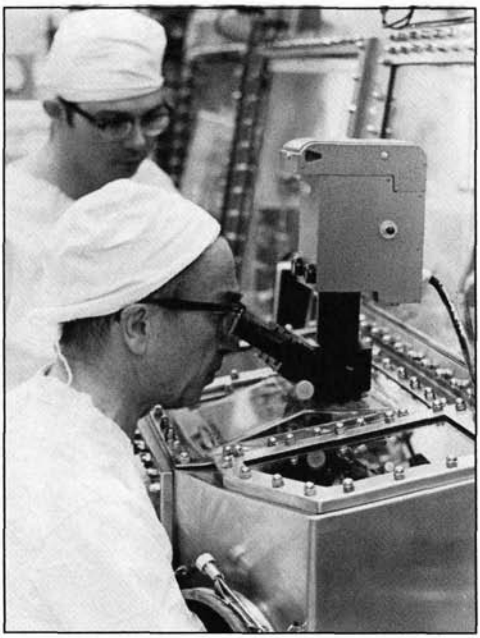

Photo 54. Prof. Clifford Frondel observing a lunar sample in a microscope whose optical path crosses the gas-tight, two-way biological barrier during the Apollo 11 preliminary examination and sample quarantine. Technician Dave Pettus at rear. (NASA photograph S-69-29682)

spotty diffraction pattern with 12 lines for olivine. By chance of orientation, however, the strongest line was missing. Once the first period of caution was over, data started coming out quickly. All the large crystalline rocks were basaltic, but the composition of one of the pyroxenes was something new. The breccias were composed mostly of basaltic rock fragments and glass.

Dr. Ross Taylor, of the PET, took an optical emission spectrograph shot of a lunar basalt. After seeing the bright white color of the "burn," Taylor remarked, "Whatever it is, it has a high titanium content." Several other samples displayed high titanium values. The common opaque mineral in the basalts from Tranquility Base was ilmenite, an iron-titanium oxide.

I opened up the Contingency Sample (Photo 55), which proved to be a marvelous miniature collection of lunar rocks and fine-sized particles. If this been our only sample brought back by Apollo 11, it still would have been a tremendous success.

Photo 55. The author unpacking and describing the contingency sample in the LRL during the Apollo 11 sample quarantine period. (NASA photograph S-69-40532)

In the samples of lunar dust and fine-sized material from the lunar "soil," we found a fascinating collection of small glass spheres (Photo 56) of different colors. These were products of micrometeoroids impacting the lunar surface, melting minerals and rocks, splashing the melt into near lunar space, and the solidified melt falling back to the surface. We would see these from all the lunar landings.

Warner had assembled a data storage and retrieval system for the lunar sample data. At the end of each shift, the new sample data was typed into the data system so it could be accessed by LSAPT or PET members outside the biological barrier. It was time to start compiling the data into a lunar sample catalog, which would be distributed to each sample investigator along with his sample.[23]

Armstrong, Aldrin, and Collins were released from quarantine on August 10, along with the Crew Reception Area staff. The PET also prepared a summary article documenting the results of the preliminary examination that would be published in a major journal of wide circulation.[24] Many of the PET members worked hard to prepare this initial article. The following 18 conclusions were drawn in this article:

1. The fabric and mineralogy of the rocks divide them into two genetic groups: (i) fine- and medium-grained crystalline rocks of igneous origin, probably originally deposited as lavaflows, dismembered, and redeposited as impact debris and (ii) breccias of complex history.
2. The crystalline rocks, as shown by their modal mineralogy and bulk chemistry, are different from any terrestrial rock and from meteorites.

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[23]*NASA Lunar Sample Information Catalog, Apollo 11* (Lunar Receiving Laboratory, Manned Spacecraft Center, August 31, 1969). Only 400 copies of this catalog were printed, and it is now considered a collector's item.

[24]The Lunar Sample Preliminary Examination Team, "Preliminary Examination of Lunar Samples from Apollo 11," *Science*, vol. 165 (1969), 1211–1227.

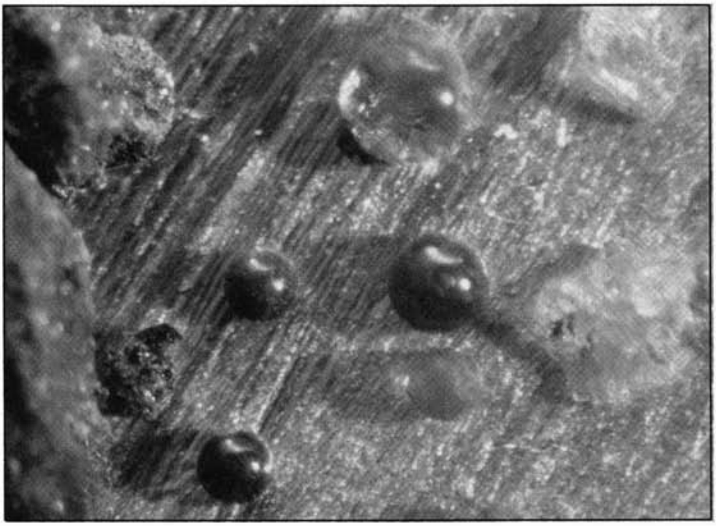

Photo 56. Glass spherules formed from the impacts of micrometeoroids into the lunar surface layer. Diameter of the largest spherule is approximately 0.5 mm. These are abundant in the fine-sized surface material at all landing sites. (NASA photograph S-69-45182)

3. Erosion has occurred on the lunar surface in view of the fact that most rocks are rounded and some have been exposed to a process which gives them a surface appearance similiar to sandblasted rocks. There is no evidence of erosion by surface water.
4. The probable presence of the mineral assemblage iron-troilite-ilmenite and the absence of any hydrated minerals suggest that the crystalline rocks were formed under extremely low partial pressures of oxygen, water, and sulfur (in the range of those in equilibrium with most meteorites).
5. The absence of secondary hydrated minerals suggests that there has been no surface water at Tranquility Base at any time since the rocks were exposed.
6. Evidence of shock or impact metamorphism is common in the rocks and fines.

7. All the rocks display glass-lined surface pits which may be caused by the impact of small particles.
8. The fine material and the breccia contain large amounts of all the noble gases, which have elemental and isotopic abundances almost certainly indicative of origin from the solar wind. The fact that interior samples of the breccias contain these gases implies that the samples were formed at the lunar surface from material previously exposed to the solar wind.
9. The potassium-argon isotopic measurements on igneous rocks show that they crystallized three billion to four billion years ago. The presence of nuclides produced by cosmic rays shows that the rocks have been within one meter of the surface for periods of 20 million to 160 million years.
10. The level of indigenous organic material capable of volatilization or pyrolysis, or both, appears to be extremely low (that is, considerably less than one part per million).
11. The chemical analyses of 23 lunar samples show that all rocks and fines are generally similar chemically.
12. The elemental constituents of lunar samples are the same as those found in terrestrial igneous rocks and meteorites. However, several significant differences in composition are apparent: (i) some refractory elements (for example, titanium and zirconium) are notably enriched and (ii) the alkali and some volatile elements are depleted.
13. Elements that are enriched in iron meteorites (that is, nickel, cobalt, and the platinum group) were not observed, or such elements are very low in abundance.
14. Of 12 radioactive species identified, two were cosmogenic radionuclides of short half-life, namely manganese 52 (5.7 days) and vanadium 48 (16.1 days).
15. Uranium and thorium concentrations lie near the typical values for terrestrial basalts; however, the ratio of potassium to uranium determined for lunar surface material is much lower than

such values determined for either terrestrial rocks or meteorites.

16. The high aluminum 26 concentration observed is consistent with the long exposure age to cosmic rays inferred from the rare-gas analysis.
17. No evidence of biological material has been found in the samples to date.
18. The lunar soil at the landing site is predominantly fine-grained, granular, slightly cohesive, and incompressible. Its hardness increases considerably at a depth of 15 centimeters. It is similar in appearance and behavior to the soil encountered at the Surveyor landing sites.

For several years, I had been teaching geology courses at night at the University of Houston. The Geology Department had one disgruntled faction. The department chairman resigned, a temporary chairman was elected, and I was asked to interview for the job. After thinking it over for a few days, I agreed to interview as a candidate for chairman. I was sure I could handle the administrative chores and felt I could lead the department to better performance. It also was clear that after the first lunar landing and sample return I would have to work in a university or research lab environment in order to have the opportunity to pursue serious research with the samples. I suggested I could join the Geology Department faculty after the Apollo 11 preliminary sample examination. I also wanted time to do my own research on the lunar samples. The university agreed. I gave my bosses several months' notice, but they waited until two weeks before I left to appoint my successor as curator. As it turned out, a number of scientists resigned from NASA at about the same time and, when interviewed, had similar criticisms of the space agency, complaining particularly about the lack of attention given to scientific goals.[25]

During the interim before the preliminary sample examination was complete, one of my big bosses called me. He had received an

[25]M. Mueller, "Trouble at NASA: Space Scientists Resign," *Science*, vol. 165 (1969), 776–777, 779.

inquiry from the White House staff, who wanted to know which lunar rocks we could provide as handsome presentation pieces for various dignitaries and politicians. My reply was "NONE!" "But President Nixon wants them," the big boss said. "Tell him he can't have them," I replied. I threatened to "blow the whistle" if they forced the issue while I was curator. How could we hand over precious scientific materials, for which men had risked their lives, as simple trophies? They got the message. I heard no more on the matter, but I had made a powerful enemy in the NASA chain of command because I had put him in a very awkward position.

The sample quarantine period was over, the *Lunar Sample Catalog* had been compiled and reproduced, and it was time to distribute the samples as recommended by LSAPT to approximately 144 principal investigators from 16 countries. The detailed work on the lunar samples was just beginning.

I was invited, together with a colleague, to bring a lunar sample and make a brief appearance on "CBS Evening News," which was anchored by Walter Cronkite. The spot was to be a live segment televised from a small studio atop a hotel across the road from the space center. The 12-foot-by-12-foot studio contained a mobile TV camera with a super wide-angle lens. We arrived at the studio at the appointed time, toting a large lunar sample carefully packaged in a gas-tight clear plastic container. We met the news reporter in charge of the segment, who told us we had exactly one and one-half minutes of live time. He reviewed with us the questions he would ask, and we briefly rehearsed our answers. We were both given earphones so we could hear the sound from the news show and the voice of a program director who was counting down to cue time. "Thirty seconds!" the director said. We were standing close together in front of the camera, with the lunar sample on a small table in front of us. "Twenty seconds!" the voiced boomed in our ear phones. When I looked at my colleague, he was visibly shaking. The newsman noticed, also, and began to look worse than my colleague. The voice in the earphone counted from 10 to "You're on!" as we heard Cronkite say, "And now, we go live to the Johnson Space

Center." The camera began wide, showing the three of us and the sample, but cut quickly to a close-up of the sample. The news reporter asked his questions, and I answered them while my colleague quickly disconnected his microphone and earphone and crawled away under the camera—a bit distracting, to say the least. Although my colleague had been on live TV and radio interviews a number of times, he got a bad case of "stage fright" this time. His exit was not visible on the transmitted image, but when the camera moved back to a wide view, one of the subjects was missing.

In November 1969, the annual meetings of the Geological Society of America (GSA) were held in Atlantic City, New Jersey. The Apollo 11 astronauts were invited to the meetings as honored guests and were awarded lifetime fellowships in the society at the annual banquet. I received an invitation to the GSA president's cocktail party, which preceded the banquet, though I wasn't sure why I had been invited. I brought my invitation, which was collected at the door, and entered a small ballroom with a couple of bars set up. At one end, a crowd of people was noisily trying to get close to Neil Armstrong. I could see from Armstrong's face that he was dazed and exhausted. Muehlburger, who was nearby, and I stepped into the crude line and worked our way toward Armstrong. When we finally reached Armstrong, he didn't recognize us for a few seconds. We reminded him who we were and told him to stand easy for awhile. We sent a friend to get him a drink and told him not to talk but to rest for a few minutes. Anxious autograph seekers were pushing against our backs, but we stood firm. After a few minutes the light came back into his eyes. He thanked us and assured us that he really could continue. We moved away, knowing that the hardest part of the lunar landing for Armstrong was dealing with the ensuing fame. The crowd didn't mean to be "pushy," but geologists so identified with a crew picking up rocks on the Moon that their enthusiasm got the best of them. I'm sure Armstrong was glad to see the cocktail party end and the banquet begin—at least he could rest a little at the head table. The remainder of the evening went as planned. Armstrong delivered a brief speech and received a standing ovation. Feeling a little sad, I walked back to my room, hoping we would soon have another lunar crew so the public affairs duties would be spread around.

Even now, when I meet one of the Apollo 11 crew members at a social gathering or technical meeting, I sense in each of them an intangible special quality. Perhaps it is a particular confidence or presence that is borne by those who have shared a unique experience or survived dangerous circumstances. One thing is certain: Neither we nor they can ever separate ourselves from the experience and knowledge gained by making the first trip to the Moon. We can never again view the Moon with the same mystery and naive ignorance of those before us.