The Crew

The prime crew consists of Gene Cernan, Commander, Harrison H. Schmitt (better known as Jack Schmitt), LM pilot, and Ron Evans, CM pilot. Cernan was pilot on the two-manned Gemini 9 Mission, backup pilot for Gemini 12, backup LM pilot for Apollo 7, and the LM pilot on Apollo 10 (in 1969). You may recall that Apollo 10 was the first really comprehensive lunar orbital flight test of the LM. On that mission, the LM separated from the CM in lunar orbit and descended to within 8 nautical miles of the lunar surface. Cernan has logged more than 264 hours in spaceflight. He was the backup commander for Apollo 14.

Jack Schmitt is the first geologist to visit the Moon and to study its rocks at first hand. The son of a mining geologist, he is eminently qualified. He has studied at the California Institute of Technology, University of Oslo in Norway, and Harvard University. He has logged more than 1200 hours in jet aircraft. He worked as a geologist in Norway, in southeastern Alaska, and in the U.S. Geological Survey's Astrogeology Branch at Flagstaff, Ariz. He served as backup LM pilot for Apollo 15.

Ron Evans has served as a member of the astronaut support crews for Apollo 7 and 9 and as backup CM pilot for Apollo 14. He has accumulated more than 3,500 hours in jet aircraft.

The Apollo 17 backup crew consists of John Young, Stu Roosa, and Charlie Duke. Each of them has flown to the Moon before—John Young and Charlie Duke visited the Moon's surface on Apollo 16, only a few months ago, and Roosa was

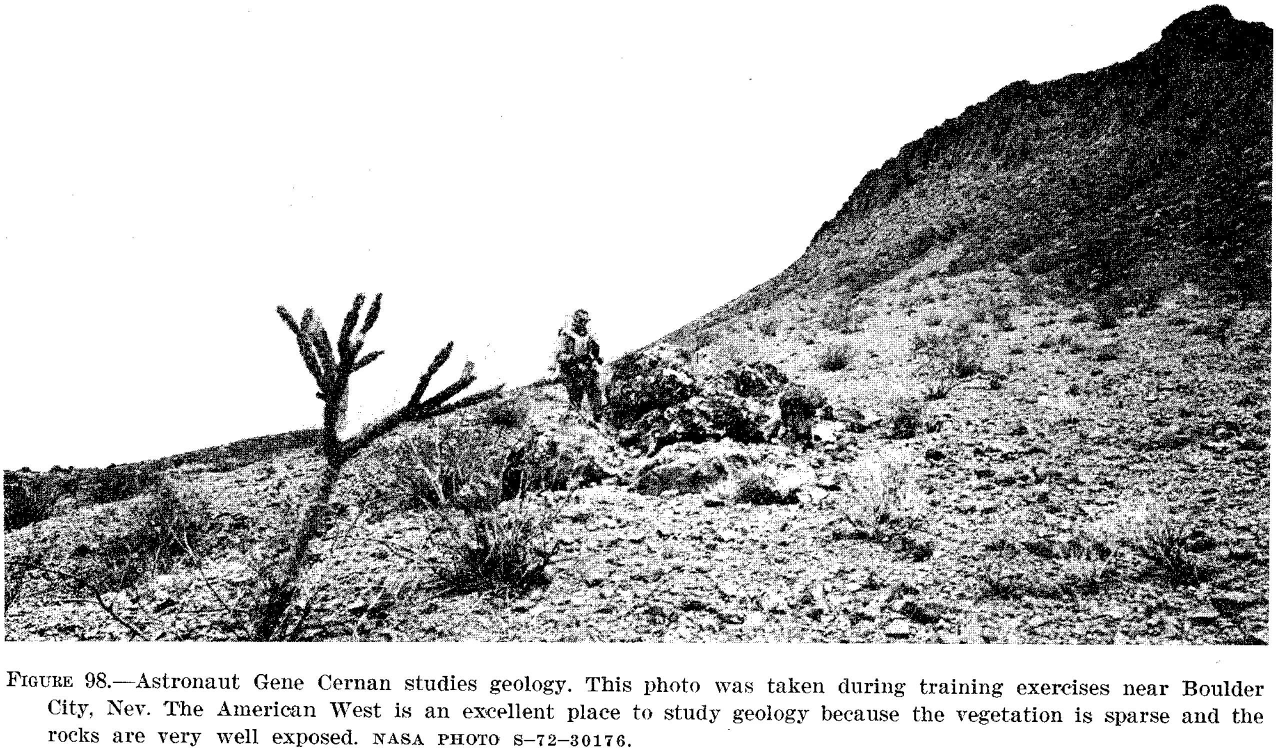

FIGURE 98.—Astronaut Gene Cernan studies geology. This photo was taken during training exercises near Boulder City, Nev. The American West is an excellent place to study geology because the vegetation is sparse and the rocks are very well exposed. NASA PHOTO S–72–30176.

the CM pilot on Apollo 14, 2 years ago. Several photographs of the prime and backup crews are shown in figures 98 through 107.

This crew, like previous ones, has undergone intensive training during the past few months and somewhat more casual training during the last few years. In addition to the many exercises needed to learn to fly their spacecraft proficiently, the astronauts have learned much about science, and in particular, about lunar science. After all, they will each spend many hours on the Moon or in orbit around the Moon performing scientific research.

The surface astronauts have had tutorial sessions with many of the nation's best scientists. They are able to set up experiments, such as those of ALSEP, but more importantly, they understand the scientific purposes behind the various experiments.

Most of the time on the lunar surface during Apollo 17 will be spent observing geologic features and collecting samples. Obviously anyone can pick up rocks with which to fill boxes and bags. Only a person highly trained in the geosciences, however, can properly select those few rocks, from many, that are likely to yield the greatest scientific return when examined in minute detail in the laboratory back on Earth. The Apollo 17 crew has spent many hours studying rocks under the guidance of geologists from the U.S. Geological Survey, several universities, and NASA's Manned Spacecraft Center.

FIGURE 99.—Astronauts Schmitt and Cernan. Notice that sampling tools, like the ones to be used on the Moon, are used during the practice exercises. Each astronaut carries a Hasselblad camera, sample bags, cuff checklists, and simulated backpacks. Schmitt carries a scoop and Cernan carries tongs. NASA PHOTO S–72–30170.

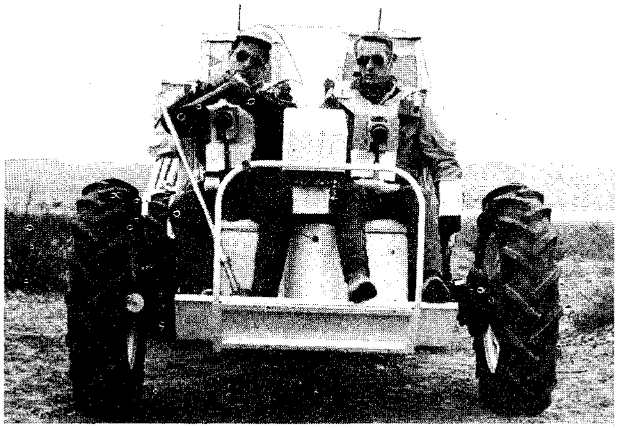

FIGURE 100.—Schmitt and Cernan ride the Explorer. The only model of the lunar Rover used for training is kept at the Kennedy Spacecraft Center. So the U.S. Geological Survey built an inexpensive version, nicknamed Explorer, for use on geological field trips. NASA PHOTO S-72-30173.

FIGURE 101.—Astronaut Ron Evans, Apollo 17 command module pilot. He is shown studying geology in Iceland about 5 years ago. Each astronaut has studied and practiced for many years for this particular mission. The observations of the Moon to be made by Evans from his vantage point in the CM will be greatly enhanced by his extensive knowledge of geology obtained over the years. NASA PHOTO S-67-38518.

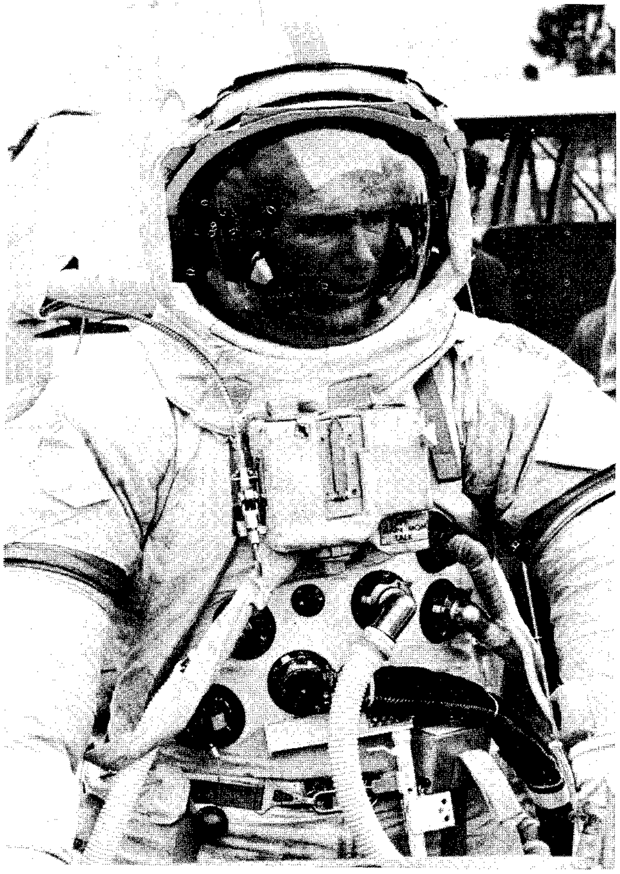

FIGURE 102.—Astronaut Gene Cernan. This photo was obtained during the spring 1972 at a practice session intended to find any "bugs" in the various experiments. To save the cost of another astronaut suit, Cernan was practicing that day in the suit that had actually been worn on the Moon's surface by Dave Scott. NASA PHOTO S-72-35043.

FIGURE 103.—Astronaut Gene Cernan. During training exercises, the observations reported by the astronauts via radio are recorded on magnetic tape and later analyzed by members of the training group (at the Manned Spacecraft Center and U.S. Geological Survey) for accuracy. NASA PHOTO S-72-30182.

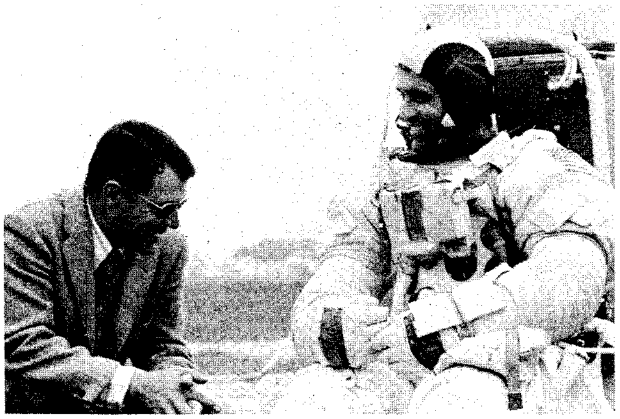

FIGURE 104.—Mission Scientist Bob Parker and Jack Schmitt. Parker, also an astronaut, helped solve many problems associated with the scientific equipment to be carried to the Moon, coordinated the crew's activities, and helped the mission in many other ways. He will be the Apollo 17 Capsule Communicator (Cap Com), the main voice communications link between Mission Control and the astronauts on the Moon. NASA PHOTO S–72–35046.

FIGURE 105.—Astronauts John Young and Charlie Duke. Even though they have already visited the Moon, they continue their geological training as part of the Apollo 17 backup crew. Notice the gnomon, the Hasselblad cameras, the lunar rock hammer and their excellent choice of hats. NASA PHOTO S–72–31181.

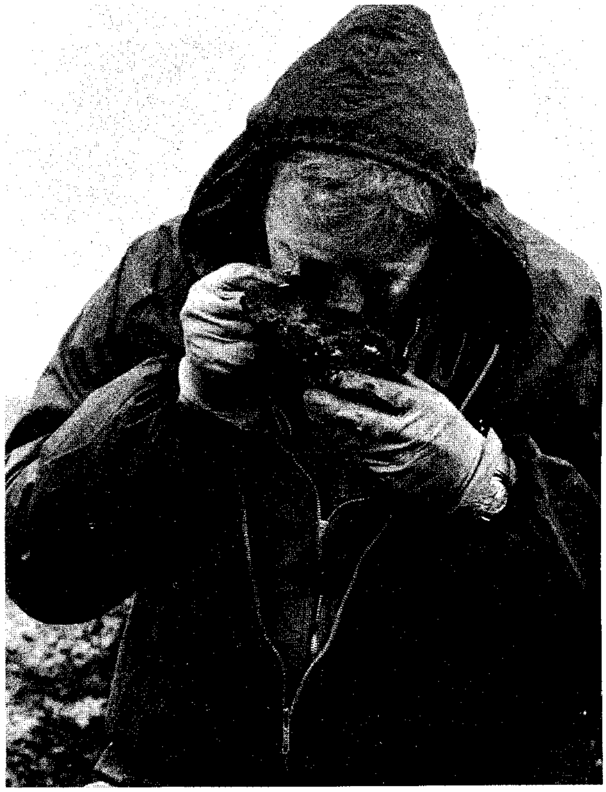

FIGURE 106.—Astronaut Stu Roosa. Even though the CM pilot will not examine rocks on the Moon's surface, an understanding of geology is absolutely essential. Roosa is shown here studying intensely a piece of basalt. This picture, taken in Iceland 5 years ago, indicates the long and continued effort of the crew to learn as much as possible about the science which they will be doing on the mission. The hand lens, probably 10X, allows him to see more clearly the individual crystals and to recognize them. NASA PHOTO S–67–38510.

FIGURE 107.—Astronauts Cernan and Schmitt discuss samples of rock collected on a training trip near Tonopah, Nev. NASA PHOTO S–72–48935.

What We've Learned About the Moon

INTRODUCTION

From the day that Galileo saw the Moon through the first telescope until July 20, 1969, when Aldrin and Armstrong walked on the Moon, man learned many things about the Moon. During those 300 years, he learned to weigh the Moon, to determine its size and shape, to measure the temperature of the surface, to estimate the electrical properties from radar waves bounced off the Moon, and to do many others without leaving the planet Earth. He even sent unmanned spacecraft to the Moon's surface and analyzed the chemical composition!

Man thus knew *many* facts about the Moon before Neil Armstrong and Buz Aldrin landed their spacecraft. Yet their historic landing opened the way for men to visit the Moon, to bring back actual material from the Moon itself, and to leave scientific instruments on the surface of the Moon to operate for several years. Just as Galileo's telescopic observations opened a new era in modern astronomy, Armstrong and Aldrin's voyage opened a new discipline in science—that of LUNAR SCIENCE.

This new science during its first 3½ years has been filled with surprises. Now surprises in science are good. They usually mean that we have discovered something that was not expected, a scientific bonus. In this section, I want to describe a few of the things we have learned about the Moon and to share with you some of the surprises.

I still vividly recall the intense excitement at the Lunar Receiving Laboratory in Houston more than 3 years ago when the Apollo 11 rock boxes were opened. The first samples of rocks and soil returned from the Moon! That was a moment some of us had worked toward for 5 to 10 years. But even so, most of us could hardly believe that we really had in our possession rocks from the Moon.

The study of those Apollo 11 samples is still being intensively explored today. The lunar samples are helping us unravel some of the most important questions in lunar science and astronomy. They include: 1. How old is the Moon? 2. Where and how did the Moon originate? 3. What history and geologic features do the Moon and Earth have in common, and what are the differences? 4. What can the Moon tell us about the rest of the solar system, and of the rest of the universe? 5. Is there any evidence of life on the Moon?

To help solve these questions, we have used highly advanced and very sensitive scientific equipment, sometimes on samples almost too small to be seen by the naked eye. Some of the equipment was designed and built specifically to work on the lunar material.

WHAT THE ROCKS TELL US

Rocks cannot literally speak. But they do contain interesting, often exciting, stories. And they do reveal their stories through the scientist's experienced eyes and sophisticated instruments. The shape, size, arrangement, and composition of the individual grains and crystals in a rock tell us about the history of the rock. Radioactive clocks tell us the age of the rock. Tiny tracks may even tell us the radiation history of the Sun during the last 100,000 years. And so on. In figures 108–110, I show the external appearance of three lunar rocks. In some aspects, their appearances resemble those of Earth rocks. The minerals are the same. The grain sizes are comparable. The shapes are familiar. And so on. But in other aspects, their appearances differ significantly. For example, the surface is pitted with tiny craters and the rocks are extraordinarily fresh.

But let me show you what we see when we study a rock with a microscope. Most rocks—lunar rocks as well as most Earth rocks—do not transmit light.

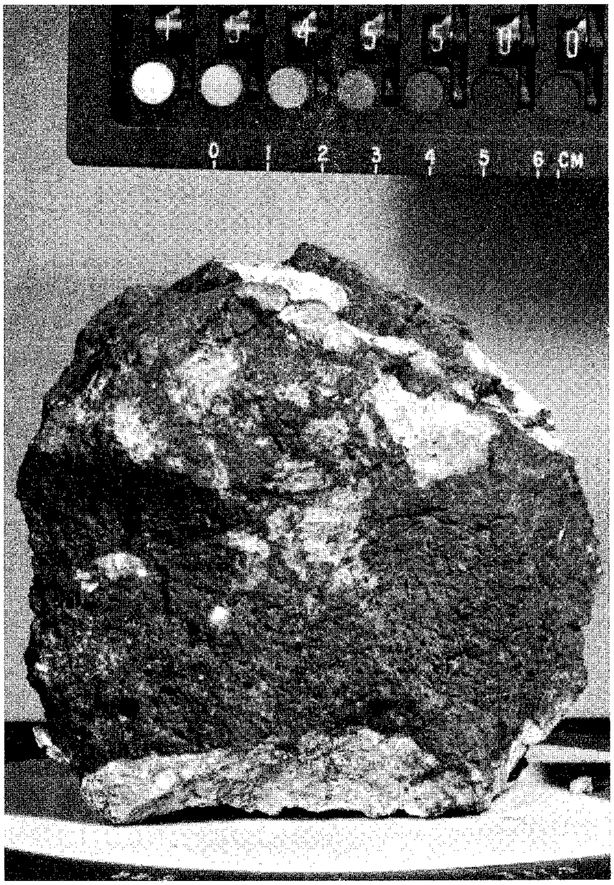

Figure 108.—The black and white rock. Sample 15455, collected on Apollo 15, is composed of two different kinds of rock and is termed a breccia. One kind shows as white, irregular spots within the second one. Note the gas holes or vugs in the dark rock. This sample weighs about ½ pound. Size of rock may be obtained with the scale shown in the figure. NASA PHOTO S-71-43889.

Yet when sliced very thin, about one-thousandth of an inch, the same rocks become transparent. Such slices are called thin sections. We study them with special microscopes.

In figure 111, we see the appearance of one kind of rock from the moon, an *igneous* rock. The term, igneous, means that the rock crystallized from a liquid, a fact that we infer from the minerals present, their arrangement and shape, and our experience of seeing similar rocks cool from the liquids erupted from volcanoes on Earth.

Note that many of the individual mineral grains transmit light but others (the completely black grains) do not transmit light. The black grains (termed opaque) are the mineral ilmenite, which is rich in titanium dioxide. On Earth, this mineral is

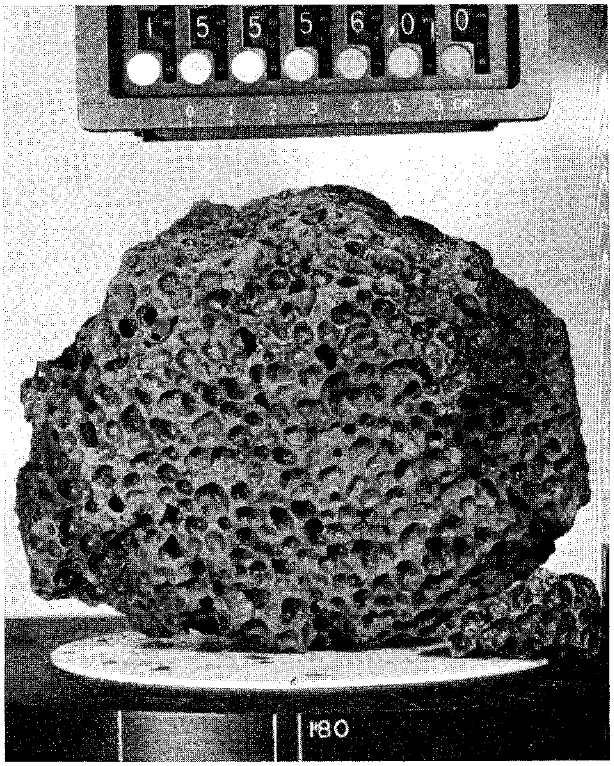

Figure 109.—Vesicular basalt. The holes, termed vesicles, were caused by gas in the rock when it was molten. This appearance is typical of many basalts on Earth that were near the top of lava flows. Some cavities are lined with glass. NASA PHOTO S-71-43328.

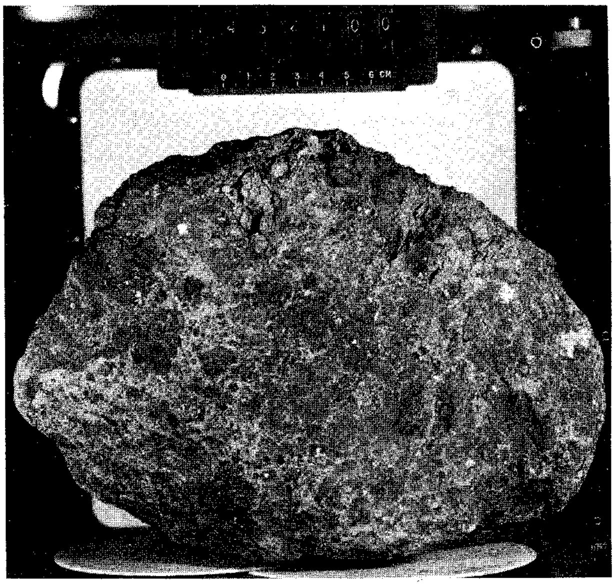

Figure 110.—Big Bertha. This sample, collected on Apollo 14, is one of the larger ones brought to Earth. NASA PHOTO S-71-56345.

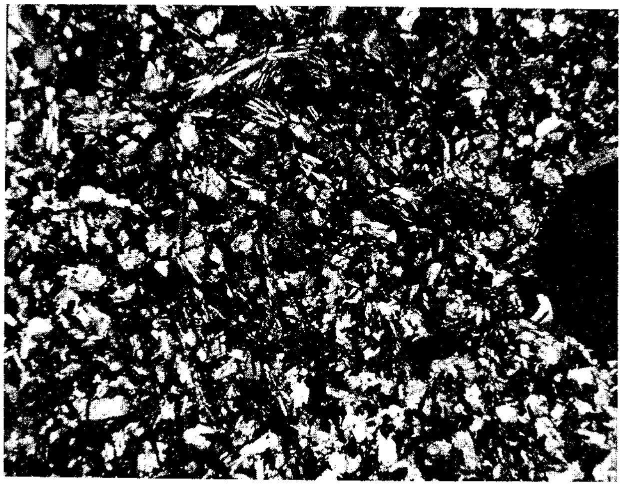

FIGURE 111.—Apollo 11 Igneous Rock. This photo was obtained with a camera mounted on a microscope. The mineral grains can be seen clearly. The small black areas are due to the mineral ilmenite which is opaque to light. The large dark area on the right is due to a hole in the rock. NASA PHOTO S-69-47902.

commercially important—it is mined for the titanium dioxide which is used for many things, including the manufacture of white paint. One of the surprises discovered immediately when examining the Apollo 11 rocks was the relatively large amount of ilmenite. Many of the rocks found at Apollo 11 site contained more than 10% titanium dioxide, an unsually large amount when judged by Earth standards. (The rocks from other missions did not contain such large amounts, though.)

Another feature that is extremely common in lunar rocks, and also in terrestrial igneous rocks, is seen in the right hand side of figure 111, the round dark area. It is a hole in the rock, termed a vesicle and was caused by gas when the rock was still liquid. We see exactly this same feature in rocks that bubble up from the volcanoes on Hawaii. Thus we are certain of the explanation.

A photomicrograph (a photograph of a thin section taken through the microscope) of another lunar rock is shown in figure 112. You can probably see that there are three different kinds of minerals. One is completely dark, literally pops out of the figure towards you, and has rather straight sides and sharp angles. This mineral is spinel and, when sufficiently large and flawless, is a beautiful gemstone. The second mineral which you can probably distinguish, also stands out though not quite as sharply as the spinel, and also occurs as discrete grains. This mineral, olivine, also has sharp edges and angles and is probably better known as peridot, the birthstone for August. The third mineral, which transmits light very well and appears colorless in thin section, constitutes the rest of the rock, filling the space around the other two minerals. It is termed feldspar and is the pink mineral in granites—a terrestrial rock commonly used for tombstones. Almost surely you have held feldspar in your hand. The familiar household cleansing and scouring powders, such as Ajax, are mostly feldspar.

And finally, you can see in the left hand side of the figure a few dark spots that represent opaque grains, probably ilmenite; there may also be metallic iron with a small percentage of nickel.

From figure 112, let me illustrate two ways in which we "read" the history of a rock from the thin section. Because the grains of ilmenite, spinel, and olivine have their characteristic crystal shapes and are surrounded by the feldspar, we know that the feldspar crystallized last. Secondly, note the thin zone near the bottom in which the individual grains are all smaller than elsewhere. This zone indicates that the bottom part of the rock was broken loose from the top part and displaced slightly towards the left.

One of the major surprises—though in retrospect the "surprise" should have been expected—was the discovery in the Apollo 11 samples of large quantities of glass. Why should glass surprise us? After all, we are extremely familiar with glass. We use glass every day. So what should be surprising? Even though we are literally surrounded with glass every day, *all* of that glass is artificial. It was manufactured. On the Earth, the occurrence

FIGURE 112.—Photomicrograph of Apollo 16 lunar igneous rock 67435. Note distinctness of the individual mineral grains. See text. NASA PHOTO S-72-42390.

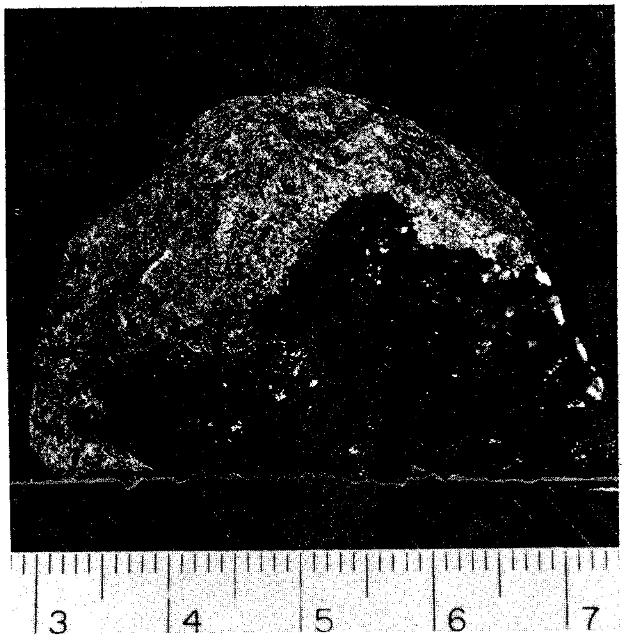

FIGURE 113.—Glass splash on lunar rock. The dark, bubbly looking material is glass that formed when a meteorite impacted the Moon. It was still hot when it hit this rock and so it stuck very securely to the rock. Sample 12017. NASA PHOTO S–70–44098.

of *natural* glass is exceedingly rare.* Most people have never seen natural glass! On the other hand, its occurrence on the Moon is extremely common. Indeed, glass is abundant in the material from each mission. It often sticks to the outside of rocks, as shown in figure 113. The glass was formed by the high pressure and temperature produced when a meteorite struck the Moon. It was splashed from the impact site, much as mud is thrown from the impact point when a pebble is dropped into a mud puddle.

Glass also occurs inside some rocks. Its appearance in thin section is shown in figure 114. The glass often forms very beautiful swirls caused by the flow of the glass before it froze.

Another surprise about the glass in the lunar rocks is that it has survived so long. The lunar rocks are 3 to 4.1 billion years old. Yet, the glass has survived this large span of time. On Earth, the oldest known glass is very young in comparison, a mere 200 million years. Most terrestrial glasses are, in fact, younger than 50 million years. The glasses that formed on Earth before 200 million years, have long since changed into individual minerals, a process called devitrification. In fact, all glasses devitrify with time. So why is the process so much more rapid on Earth than it is on the Moon? Because no water is present on the Moon. Water greatly increases the rate of devitrification. Thus a glass can persist on the Moon for 4 billion years in the complete absence of water. Yet the same glass on Earth in the presence of water would devitrify within a few tens of millions of years.

Water is indeed very rare on the Moon. The widespread abundance of ancient glasses is very strong evidence. But in addition, none of the minerals of the lunar rocks contains water. (Actually two or three occurrences of hydrous minerals have been reported but they are extremely rare.) The absence of water on the Moon surprised most lunar scientists. Of course, we had known that at present, because of the extremely thin—almost nonexistent—lunar atmosphere, there could be no free water on the surface of the Moon. Yet because some lunar features such as the beautiful valley at Hadley-Apennine, the Apollo 15 site, resemble features on the Earth that we know to have been formed by water, we had expected that perhaps in the past there had been significant quantities of water on, and inside, the Moon. But we now know that hypothesis to be completely false.

Incidentally, the absence of water on the Moon has great practical significance for mankind. I expect that man will soon live in permanent colonies

FIGURE 114.—Photomicrograph of lunar rock. This photo taken through a microscope shows the typical appearance of lunar glass. Most of the material in this field of view is glass. Note especially the swirls; they were caused by flow of the glass when it was still fluid. NASA PHOTO S–71–23092.

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*However, you may have seen obsidian, a black-to-brown volcanic glass.

on the Moon. Thus the absence of water means that supplies of water must be either carried with the colonists (as the present-day astronauts), or manufactured on the Moon. In a sense, this lack of water also has immediate benefits to Apollo 17 science. It is exactly this absence of water that causes the electrical properties to be such that my experiment, SEP, will be able to "see" deeply beneath the surface.

Another kind of lunar rock, also extremely common, is illustrated in figure 115. It is a breccia which is a rock that contains pieces of other rocks. On the Moon, breccias are formed under the intense pressure and temperature produced by meteorite impacts. Thus the rocks that existed before an impact, as well as the soils, are welded together under the high pressures and temperatures. In figure 115, the darkish material is glass that "cements" individual mineral grains as well as individual rock particles. The event that produced the glass was undoubtedly the last of several events. At least two other events are also recorded in this rock. Note that the large chunk of rock in the lower part of the figure contains other mineral grains, as well as pieces of other preexisting rocks. In addition, the darkish grain in the upper left hand part of the figure contains other grains. Thus a series of events occurred on the Moon that formed first, the small rock particle seen in about the upper third of the darkish rock fragment, second the darkish rock fragment, and third the dark glass that now encloses everything. Such is the complex history of this lunar rock.

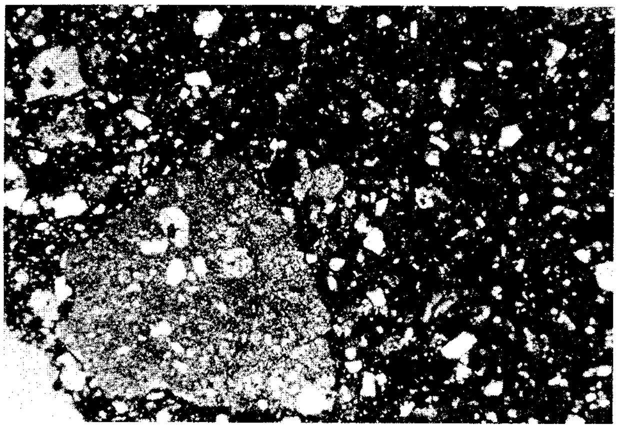

FIGURE 115.—Lunar Breccia. Fragments of several different rocks are apparent in this photomicrograph. See text. NASA PHOTO S–71–23092.

FIGURE 116.—Lunar Anorthosite. This photomicrograph shows that the rock is almost entirely feldspar; therefore, the rock is an anorthosite. Small amounts of other minerals may be seen here as small lightish grains enclosed within grains of feldspar. NASA PHOTO S–71–51778.

What about the minerals that we have seen in the Moon rocks? Most of them are similar to the ones with which we are familiar on Earth, though with some notable exceptions. The common minerals are feldspar (familiar to you from Ajax), olivine (in gem form, peridot), pyroxene (a mineral composed chiefly of iron, magnesium, calcium, silicon, and oxygen), and spinel. Quartz (silicon dioxide), an extremely common terrestrial mineral, is completely missing on the Moon. And finally, native iron is present, though in small quantities, in many of the lunar rocks. Even "rusty" iron has been seen in the preliminary examination of the Apollo 16 samples.

Still another kind of rock is shown in figure 116. It consists almost entirely of a single mineral, feldspar. The stripes across the grains, characteristic of feldspar, are caused by the individual sections having a special orientation with respect to the rest of the mineral grain. In this figure, you can see a very small amount of another mineral, olivine. The recognition that such rocks as this, termed anorthosites, probably form the highlands region of the Moon, is one of the most exciting chapters in Lunar Science. In the Apollo 11 material, very tiny fragments of anorthosite were discovered in the lunar soils. The hypothesis that such material might form the lunar highlands was suggested at that time. The evidence was certainly not very strong but the hypothesis was surely interesting. Furthermore, it "explained" the previous discovery by two scientists at the Jet Propul-

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Figures 111 through 116 inclusive are available on a full color poster. Order until December 31, 1973 from Box 2003, Kankakee, Ill. 60901.

sion Laboratory, William Sjogren and Paul Muller, that the rocks beneath the lunar highlands are less dense than the rocks beneath the lunar mare. Anorthosites were known to be less dense than basalts. The hypothesis was strengthened by finding additional anorthosites on each of the later missions. Indeed rather large samples of anorthosite were found on both the Apollo 15 and Apollo 16 Missions. And finally, an Apollo 15 *orbital* experiment, the X-ray fluorescence experiment (described in detail in the Apollo 16 guidebook) showed that the elements aluminum and silicon are in the proper ratio in the highlands for anorthosite.

Anorthosites are very special rocks. The observation that anorthosite consists almost entirely of a single mineral is very important. The chemical processes that lead from the ordinary igneous rocks—like basalt—to an anorthosite are very complex. An anorthosite is a "highly refined product." The processes are similar to the ones used on Earth in petroleum refineries to change crude oil to such diverse products as asphalt for roads, lubrication greases, motor oil, kerosene, jet fuel, automobile gasoline, aviation gasoline, and dozens of other products. Like aviation gasoline, the anorthosite is the final product of a series of very complex chemical processes.

All the lunar rocks are very, very old. Their ages range from 3 to 4 billion years. The oldest known terrestrial rock is about 3½ billion years old and rocks older than 2 billion years are extremely rare. How are such ages measured? By radioactive clocks. The rocks contain radioactive elements, such as uranium, that change slowly, and at a known rate, into other elements. From the ratio of daughter product to the parent radioactive element, measured with highly sensitive instruments, we can estimate the age.

What about life on the Moon? We have found no chemical evidence that living things (except 10 very lively astronauts!) have ever been on the Moon. No fossils. No microorganisms. No traces of biologically formed chemicals. Nothing. Yet, there do appear to be extremely small amounts of amino acids and possibly other related organic compounds in some of the lunar soil. Recently, such molecules as formaldehyde, ammonia, and methyl alcohol have been detected as clouds in remote space. Such findings have led many to speculate that even though there is no evidence of life on the Moon, life, even intelligent life, must exist elsewhere in the universe. Undoubtedly, this question will remain a major one for future investigations.

Nearly 800 scientists in the United States and 17 foreign countries are studying the lunar samples today. Even though about 600 pounds of lunar samples have been brought to Earth so far, and we expect to get another 200 pounds from Apollo 17, we are still being very conservative in how much we use. Most of us who work on the samples actually receive a piece smaller than one-fourth inch on a side; a very few receive larger pieces. All material (except that which is used in a few experiments that consume the material) is returned to NASA when our work is fininshed. Less than 10 percent of the total samples have been used so far for analysis; the other 90 percent will be carefully preserved for scientific studies in future years, probably using new and more powerful analytical tools not yet known today. These samples will be a priceless scientific heritage as well as a special kind of enduring monument to the memory of the astronauts and to the many scientists, engineers, taxpayers, and others who made the Apollo missions possible. An inventory of lunar samples made in July 1972 is shown below. Small quantities have been given by the President to foreign heads of state and to the governors of each State.

WHAT THE LUNAR SURFACE EXPERIMENTS TELL US

The scientific experiments left on the Moon by the astronauts have sent data to Earth over microwave radio links for 3 years. It is hoped that they will continue to operate for several more years. A complete listing of these experiments is given in Table 4 of the Appendix. But let me discuss here only a few of those experiments that have helped us understand the interior of the Moon. They too have given us many surprises.

Very sensitive instruments, termed seismographs, measure extremely small vibrations of the Moon's surface. These instruments are similar to the familiar ones used by doctors to listen to your heartbeat. With them, we can listen back on Earth to the vibrations on the Moon. Some of those vibrations are caused by naturally occurring events, others by impacts on the Moon of parts of spacecraft, still others by meteorites. The spacecraft

Lunar Sample Inventory

	Apollo Missions				
	A-11	A-12	A-14 (grams)	A-15	A-16
Amount returned	21, 694	34, 369	42, 927	77, 380	95, 476
Used for Biotesting	702	538	589	158	[2] 72
Destructive Analysis	4, 225	2, 681	2, 823	3, 010	2, 933
On display	2, 113	1, 925	247	660	[2] 20
Processing loss at MSC	[1] 650	[1] 600	[1] 200	[1] 200	[2] 40
Available for future generation experiments	15, 218	29, 669	39, 315	74, 012	[2] 92, 431
Percent of returned sample used for scientific investigations and displays	25. 8	13. 4	7. 2	4. 7	3. 1

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[1] Estimated.

[2] Preliminary figures, allocation, and sample processing still in progress at time of inventory.

impacts have been especially valuable to our study of the Moon's interior. We now believe that the Moon has a crust of rocks that differ greatly from the rocks deeper in the Moon. This crust is roughly 30 to 40 miles thick. Its existence implies that the early geological history of the Moon resembles that of the Earth which also developed a similar crust.

By comparison with the Earth, the Moon is extremely quiet. More than one million earthquakes occur on the Earth each year, yet only a few hundred seismic events—sometimes termed moonquakes—occur on the Moon.

The seismic properties of the lunar crust were greatly surprising. Very small signals from the impart of each spacecraft caused the Moon to ring like a bell for several hours. Such behavior of the Earth is not entirely unknown but occurs only with the largest of earthquakes. Similar signals on the Earth would have died completely after a few minutes. Perhaps this difference in behavior is caused by the absence of water in the Moon, the presence of a vacuum, and the lower temperature of the Moon's crust.

Another surprise, as well as some exciting implications, was provided by measurement of the Moon's magnetic field. Now the magnetic field of the Moon (and also the Earth) has two parts, one that changes with time and one that is steady and does not change rapidly with time.

The *steady* part of the Earth's magnetic field is about 50,000 gamma (the usual unit of magnetic field employed by Earth scientists). It causes compasses to point approximately north-south. The steady part of the lunar magnetic field, measured at the Apollo 12 site, was about 35 gamma, somewhat more than 1,000 times smaller than the Earth's field. Yet the 35 gamma field was several times larger than we had expected. Values measured at the Apollo 14 and 16 sites were even larger! The steady part of the lunar magnetic field is undoubtedly due to the presence of natural magnetism in lunar rocks. The natural magnetism was probably inherited early in the Moon's history (perhaps several billion years ago) when the magnetic field was many times larger than today. It is much too small at present to affect the usual compass.

The other part of the lunar magnetic field, that which varies with time, is influenced greatly by the electrical properties of the interior of the Moon. Therefore, a study of the variations with time of the magnetic field will reveal the electrical properties of the Moon as a function of depth. Because the electrical properties of rocks are influenced by the temperature, we hope to use such data to measure indirectly temperatures in the interior of the Moon.

Incidentally, there is now occurring an interesting debate in Lunar Science. One interpretation of the existing data is that deep inside, the Moon is relatively cool. It may be only 600 to 800° C. Such temperatures may seem high but in comparison with the Earth's temperature, which may be five times as high, they are relatively cool. This conclusion of low temperature is not certain but *if* substantiated by later work, will be most profound because it means that the lunar material is much lower in radioactivity than the Earth. Another interpretation is that some assumption

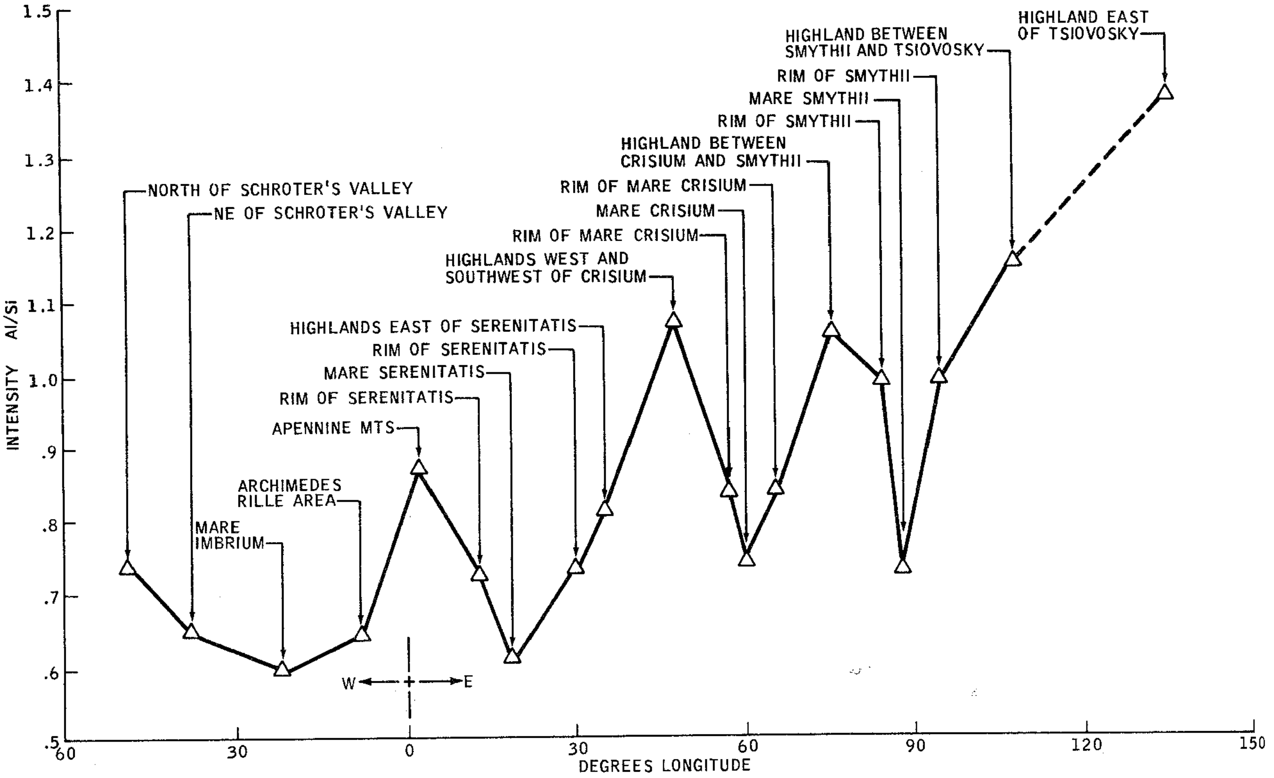

FIGURE 117.—Aluminum-silicon ratios measured along one track of Apollo 15. Note the excellent correlation between the intensity and different lunar regions. The maria have low ratios, the highlands have high values. These data support the idea that the lunar highlands consist mostly of anorthosite, an aluminum silicate rock. Similar data were obtained with identical equipment on Apollo 16. Data provided by Dr. I. Adler, the principal investigator of this experiment. NASA PHOTO S–72–16319.

in the data reduction method is incorrect and that the Moon is really hotter in the interior. It will be most interesting to watch the outcome of this debate which should be settled within a few years.

WHAT THE ORBITAL EXPERIMENTS TELL US

While the surface experiments tell us about the interior of the Moon, or about some phenomenon in the vicinity of the landing site, and the lunar rocks also tell us mainly about events that happened near the landing site, the orbital experiments give us information along a path completely around the Moon. So, in one sense, the orbital experiments allow us to extend the information collected at a very few landing spots on the Moon to much larger regions. For example, the chemical group of orbital experiments—the X-ray Fluorescence Experiment, the Alpha-particle Spectrometer, and the Gamma Ray Spectrometer have let us extend the chemical compositions obtained at the landing sites. Because of the orbital experiments, we are now quite confident that the highlands and maria *are* chemically different and that the highlands material is closely akin to anorthosite.

But not only do the orbital experiments let us extrapolate the site data, they also provide new information about the Moon that was not otherwise available. We have obtained very high quality photographs that will be used to provide a geodetic reference system for locations on the Moon that is comparable to the best yet developed for the Earth. But the current (preliminary) geologic analysis of a few of those photos has revealed the presence of several features on the Moon that had previously been suggested on the basis of less evidence. The photos of the Taurus-Littrow site have been interpreted by two geologists, Jim Head and Tom McGetchin, to indicate the presence at the Apollo 17 site of volcanic debris similar to that on Earth blown out of the volcanoes Stromboli and Etna. Head and McGetchin used slow motion photography of the eruptions of these two volcanoes, aerodynamic theory, and the effect of one-sixth gravity, to show the kind of deposits that these volcanoes would have built on the Moon. They then compared the predicted features with those shown on the lunar photos. Of course, their results will soon be tested by the Apollo 17 mission!

Recognition that materials bombarded with X-rays fluoresced allowed Dr. Isadore Adler to perform an orbital experiment to detect and measure fluorescent X-rays from the Moon. Under favorable conditions, his experiment can measure the amounts of lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminum, and silicon. The most common of these elements in lunar rocks, as well as terrestrial, are magnesium, aluminum, and silicon.

Some preliminary results obtained from the Apollo 15 flight are shown in figure 117. The ratio of aluminum to silicon (usually denoted Al/Si) is plotted against longitude for one revolution. Shown also are the locations of various features of the Moon in relation to the data. Adler and his team observed that the ratios are generally low over mare regions and high over the Highlands. Such systematic variations are clearly related to the distribution of rock types over the surface of the Moon.

There were several other orbital experiments. Each experiment has told us many important and exciting things about the Moon. I have discussed the results of some of the experiments in the section on the orbital experiments of Apollo 17. But the whole story fills a book of its own—a book now in preparation that should be finished soon after the Apollo 17 Mission.