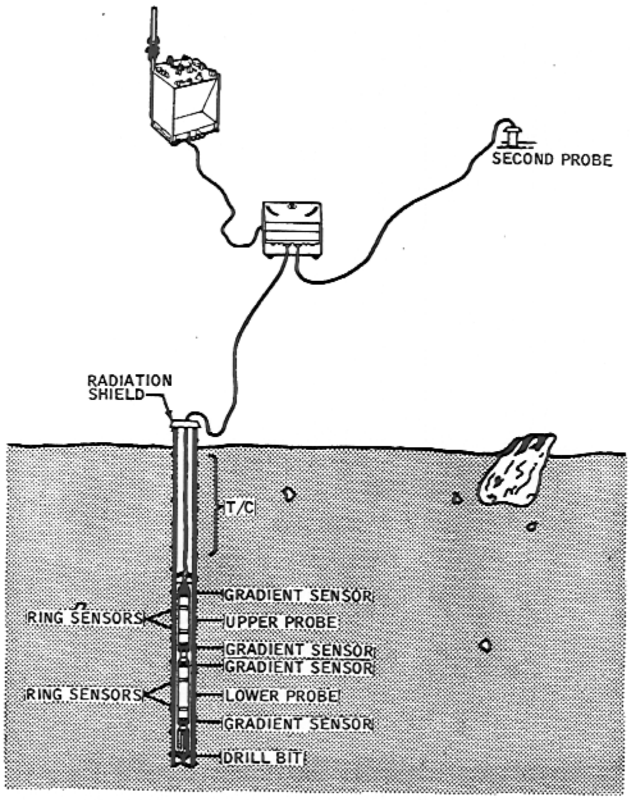

FIGURE 23.—Heat Flow Experiment. Probes are placed in two holes drilled in the lunar surface with the drill shown in figure 22. One hole is shown in the figure as a section to show the various parts. The gradient is the difference of temperature at two points divided by the distance between the points. Heat flow is measured by measuring the gradient and independently measuring the thermal conductivity; heat flow is the product of gradient and thermal conductivity. The symbol T/C indicates thermocouples that are present in the upper part of the holes.

to set limits on the amount of radioactivity now present in the Moon and to set limits on models of the thermal history of the Moon.

Passive Seismic Experiment (PSE)

The Passive Seismic Experiment (PSE) is used to measure extremely small vibrations of the Moon's surface. It is similar to seismometers used on the Earth to study the vibrations caused by earthquakes and by man-made explosions. The PSE equipment is seen in figure 24. The principle of operation is indicated in figure 25. As the instrument is shaken, the inertia of the mass causes the boom to move relative to the case. This relative motion is detected electrically by the capacitor and

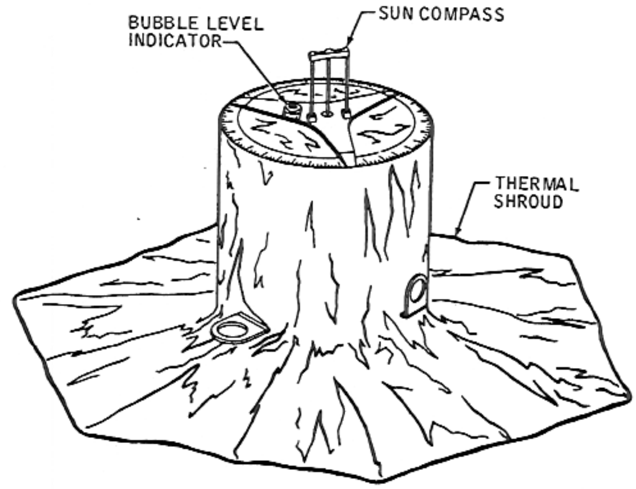

FIGURE 24.—Passive Seismometer. The instrument is covered with a blanket of superinsulation to protect it from the extreme variations of temperature on the Moon (—400° to +200°F). The principle of operation is shown in figure 25. The level, used on the Moon in exactly the same way as on the Earth, indicates whether the instrument is level. The Sun compass is used to indicate direction.

the electrical signal is then transmitted by radio to the Earth.

A typical seismic signal for the Moon is seen in figure 26. Such signals are detected at the Apollo 12 and 14 sites at the rate of about one per day. There is usually increased activity when the Moon is farthest from the Earth and also when it is nearest the Earth.

The data from the PSE, in conjunction with similar data from Apollo 12 and 14 sites, are especially valuable. They will be used to study the nature of the interior the Moon, to determine the location of moonquakes and to detect the number and size of meteoroids that strike the lunar surface.

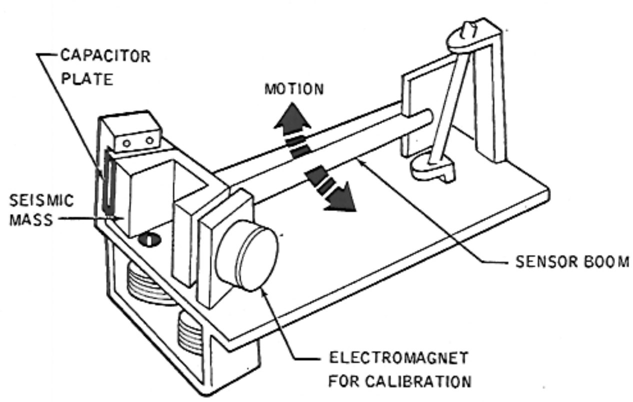

FIGURE 25.—Principle of operation of passive seismometer. See text for details.

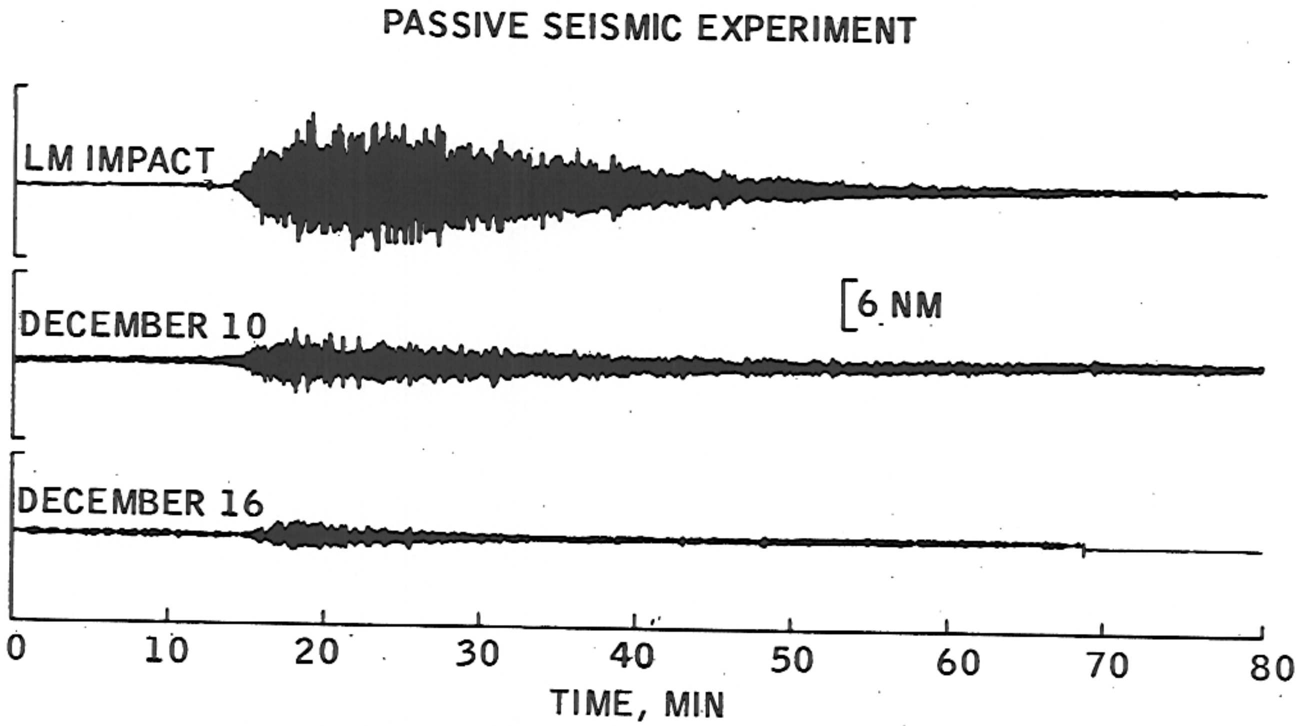

FIGURE 26.—Typical seismic signals for the Moon. These events were sensed at the Apollo 12 seismometer. To produce the largest signals shown here, the Moon's surface moved about 2 ten-thousandths of an inch.

The Moon is still being bombarded by small objects; most of them are microscopic in size. The Earth is also being bombarded but most small objects completely disintegrate in the Earth's atmosphere; they are the familiar shooting stars.

Lunar Surface Magnetometer (LSM)

The Lunar Surface Magnetometer (LSM) is used to measure the variations with time of the magnetic field at the surface of the Moon. A similar instrument was left at the Apollo 12 site. It is still sending data to Earth. None was left at the Apollo 14 site although two measurements of the magnetic field were made there with a smaller, portable magnetometer. The LSM equipment is shown in figure 27. Because the magnetic field at the surface of the Moon can change in amplitude, frequency, and direction, the LSM is used to measure the magnetic field in three directions. The sensors are located at the ends of three booms.

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 part that changes with time is caused by travelling electromagnetic waves.

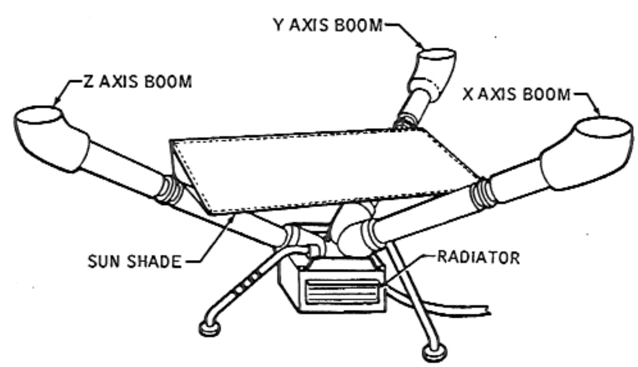

FIGURE 27.—Lunar Surface Magnetometer. Measurements are obtained as a function of time of the magnetic field at the surface of the Moon by the lunar surface magnetometer. The actual sensors are located in the enlarged parts at the end of the three booms. The plate located in the center of the instrument is a sun shade to protect the electronics in the box at the junction of the three booms from direct sunlight.

The steady part of the Earth's magnetic field, that part which does not change rapidly with time, 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. Similar measurements obtained at the Apollo 14 site with the smaller portable magnetometer revealed a magnetic field in two different spots of about 65 gamma and 100 gamma. 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 Moon's magnetic field was many times larger than today.

The LSM is also used to measure the variation with time of the magnetic field at the surface of the Moon. The variations are caused by electromagnetic waves that emanate from the Sun and propagate through space. The largest change in the magnetic field ever measured in space, about 100 gammas, was detected by the Apollo 12 LSM.

Variations with time in the magnetic field at the surface of the Moon are 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 the data from the LSM to measure indirectly temperatures in the interior of the Moon.

Lunar Atmosphere and Solar Wind Experiments

(1) *Solar Wind Spectrometer (SWS)*
(2) *Solar Wind Composition (SWC)*
(3) *Suprathermal Ion Detector (SIDE)/Cold Cathode Ion Gauge (CCIG)*

Matter is ejected, more or less continuously, by the Sun and spreads throughout the solar system. It is called the solar wind. It is very tenuous. It moves with a speed of a few hundred miles per second. The energy, density, direction of travel, and variations with time of the electrons and protons in the solar wind that strike the surface of the Moon will be measured by the Solar Wind Spectrometer. This equipment is shown in figure 28. The seven sensors are located beneath the seven dust shields seen in the picture. The data allow us to study the existence of the solar wind at the lunar surface, the general properties of the solar wind and its interaction with the Moon. The solar wind "blows" the Earth's magnetic field into the form of a long tail that extends past the Moon. Thus the SWS is also used to study the Earth's magnetic tail.

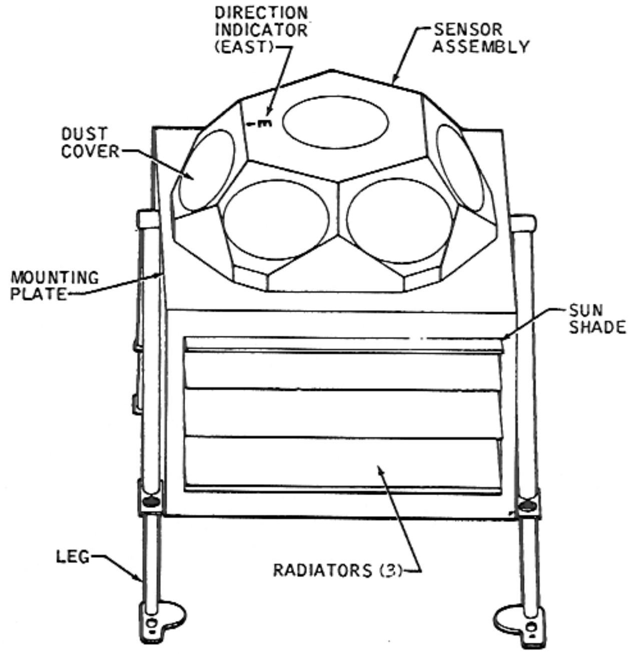

FIGURE 28.—Solar Wind Spectrometer. With this instrument, the solar wind will be studied. It measures energy, density, directions of travel, and the variations with time of the solar wind that strikes the surface of the Moon. During the journey to the Moon, this equipment is carried with the legs and sun shade folded so that it will occupy less space. The astronaut unfolds the legs and sun shade before setting it out on the Moon.

Some equipment carried to the Moon to determine the composition of the solar wind is extremely simple. The Solar Wind Composition (SWC) experiment is essentially a sheet of aluminum foil like the familiar household item used to wrap food. It is seen in figure 29. Exposed on the lunar surface to the solar wind, it traps in the foil the individual particles of the solar wind. The foil is returned to Earth and the individual elements are examined in the laboratory. Sponsored by the Swiss government, this experiment is international in scope.

Two experiments, the Suprathermal Ion Detector Experiment (SIDE) and the Cold Cathode Ion Gauge (CCIG) are used to measure the number and types of ions on the Moon. An ion is an electrically charged molecule. It may be either positive or negative, which depends on whether one or more electrons are lost or gained, respectively. Those ions on the Moon are chiefly hydrogen and helium and are largely derived from the solar wind

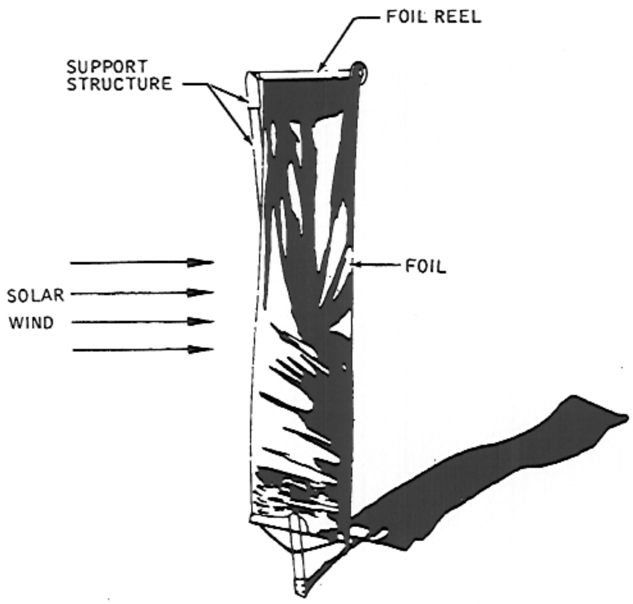

FIGURE 29.—Solar Wind Composition Experiment. Particles in the solar wind strike the aluminum foil, are trapped in it, and finally brought back to Earth by the astronauts for examination. This experiment is sponsored by the Swiss government.

but several others are present also. The hardware is illustrated in figure 30.

The SIDE is used to measure the flux, number, density, velocity, and the relative energy of the positive ions near the lunar surface. The CCIG, although a separate experiment, is electronically

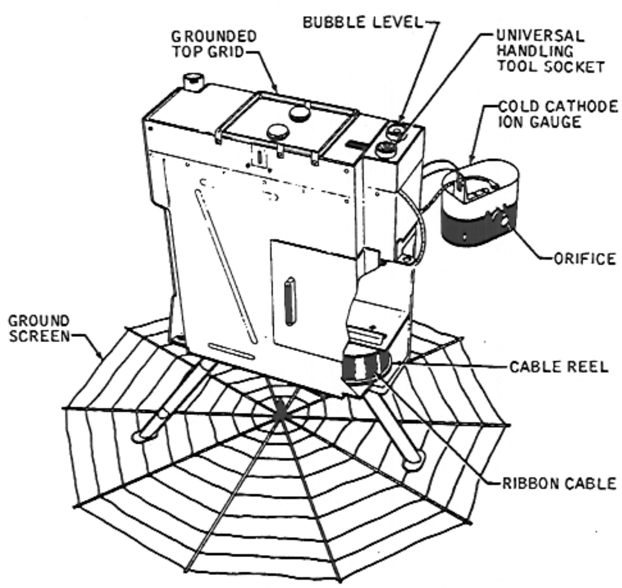

FIGURE 30.—Suprathermal Ion Detector (SIDE) and Cold Cathode Ion Gauge (CCIG). These two experiments are used to study the atmosphere of the Moon.

integrated with the SIDE. It is used to measure the pressure of the lunar atmosphere. It operates over the pressure range of 10^{-6} to 10^{-12} torr. (For comparison of these units, the Earth's atmosphere at sea level produces a pressure of about 760 torr and the pressure in the familiar Thermos vacuum bottles is about 10^{-3} torr.) The lowest pressures obtainable on Earth in vacuum chambers is about 10^{-13} torr. The pressure measured at the Apollo 14 site by CCIG was about 10^{-12} torr. At that pressure only 500,000 molecules of atmosphere would be present in a volume of 1 cubic inch. Although that number may seem like many molecules, remember that 10^{15} times as many exist in each cubic inch near the surface of the Earth! The lunar pressure varies slightly with time.

Astronauts continually release gas molecules from their suit and PLSS. The molecules are chiefly water and carbon dioxide. These additional molecules increase locally the atmospheric pressure and the CCIG readily shows the presence of an astronaut in the immediate vicinity. It is expected that the Apollo 14 CCIG will "see" the arrival of the Apollo 15 LM on the Moon from the exhaust gases.

Lunar Dust Detector (LDD)

The main purpose of the Lunar Dust Detector (LDD) is to measure the amount of dust accumulation on the surface of the Moon. It also measures incidentally the damage to solar cells caused by high energy radiation and it measures the reflected infrared energy and temperatures of the lunar surface. It is located on the ALSEP Central Station (see figure 20) and consists of three photocells.

Laser Ranging Retro-Reflector (LRRR)

The Laser Ranging Retro-Reflector (LRRR pronounced LR-cubed) is a very fancy mirror that is used to reflect light sent to the Moon by a laser. By measuring the time required for a pulse of light to travel from the Earth to the Moon, be reflected by the LRRR, and return to the Earth, the distance to that point on the Moon can be measured very precisely. Even though the distance to the Moon is about 240,000 miles, the exact distance can be measured with this technique with an accuracy of a few inches. Such data provide information about the motion of the Moon in space about the

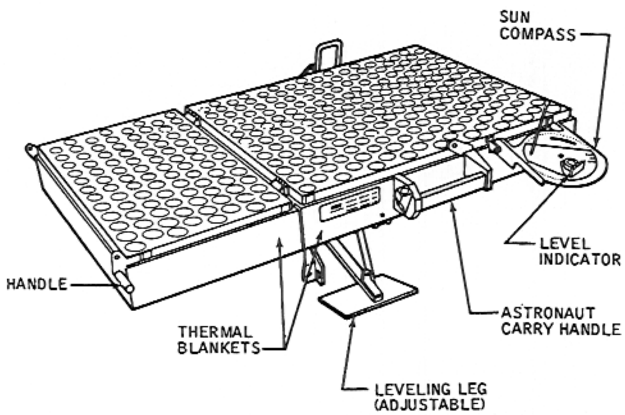

FIGURE 31.—Laser Ranging Retro-Reflector. A rather fancy mirror, the LRRR, is used to return to Earth a laser beam reflected at the surface of the Moon. There are no restrictions on its use by anyone throughout the world.

Earth, the vibrations of the Moon, and incidentally about the variations in the rotation of the Earth.

The LRRR equipment is shown in figure 31. It consists of 300 individual fused silica optical corner reflectors. Obviously, scientists in any country on Earth can use this equipment to return their own laser beams. Similar ones, though smaller, were left at the Apollo 11, 12, and 14 sites.

Lunar Geology Experiment (LGE)

Most of the time spent by the astronauts during the three EVA's will be devoted to investigation of various geologic features at the landing site and to collecting samples of rocks. Many detailed photographs will be obtained to supplement the verbal descriptions by the astronauts. Samples of the rocks present at the site will be bagged and brought back to Earth. The astronauts will use several individual pieces of equipment to help them with their tasks. In this section, I describe briefly the individual items used in studying the geology of the Hadley-Apennine region and in collecting samples for return to Earth.

Soon after the astronauts first set foot on the surface of the Moon, one will use the tool shown in figure 32 to collect a small (about 1–2 lbs.) sample of rock and soil. That sample is termed the contingency sample. It is stowed immediately on board the LM to insure that at least some material would be obtained in the unlikely event that the surface activities had to be terminated abruptly and prematurely for any reason.

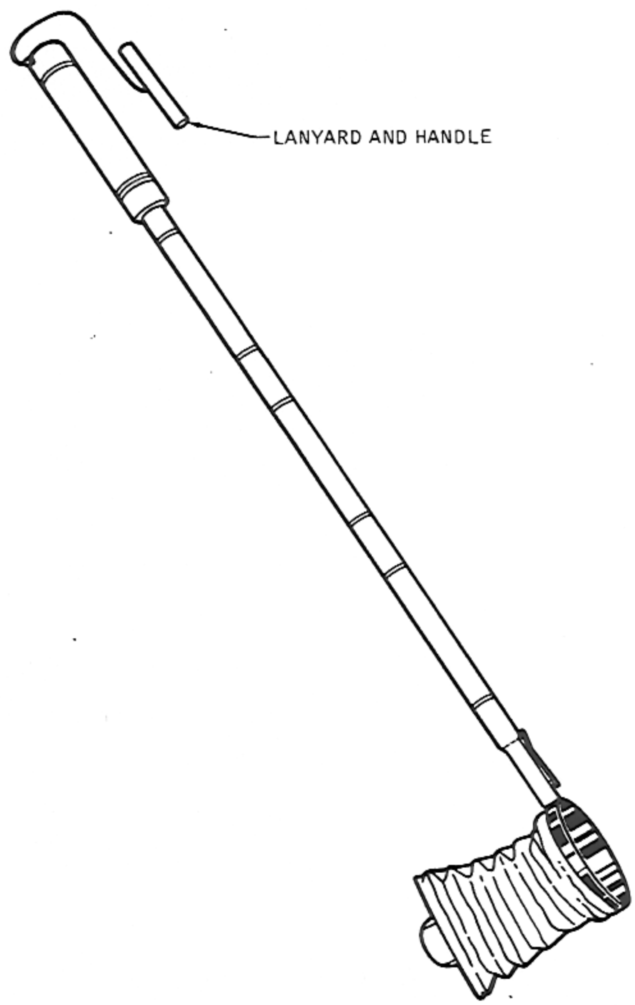

FIGURE 32.—Contingency Sampler. During the flight to the Moon, the handle is folded. Tension on the rope stiffens it so that the astronauts can scoop quickly a few rocks and some soil. The bag is made of Teflon, will hold about 2 pounds of rocks and soil, and is detached from the handle before stowage in the LM. This tool is used to collect material from the immediate area of the LM very soon after the astronauts first egress from the LM so that some samples will have been obtained if the surface activities must be curtailed and the mission aborted.

Observations made on the lunar surface of the various geological features are very important. The television camera allows us on Earth to follow the astronauts and to "see" some of the same features, though not nearly so well, as the astronauts see. The TV camera used on Apollo 14, similar to the one on this mission, is shown in figure 33. The Apollo 15 TV camera will be mounted on the Rover during the traverses.

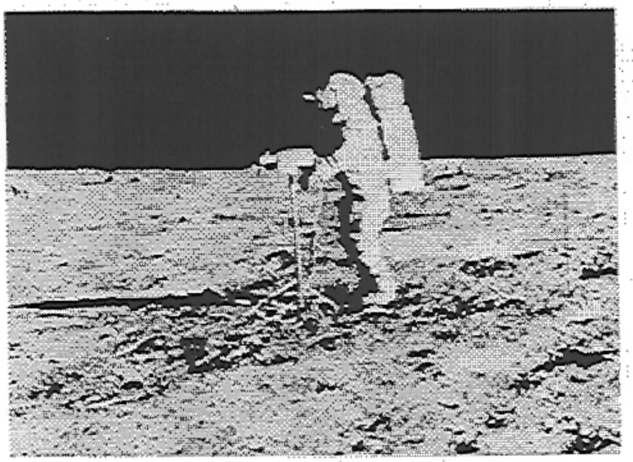

FIGURE 33.—Apollo 14 television camera. The astronaut is adjusting the TV camera to obtain the best possible viewing of activities around the LM during the Apollo 14 mission. A similar television camera will be carried aboard Apollo 15; it will be mounted sometimes on the Rover. Note the many craters in the foreground and the boulders in the distance.

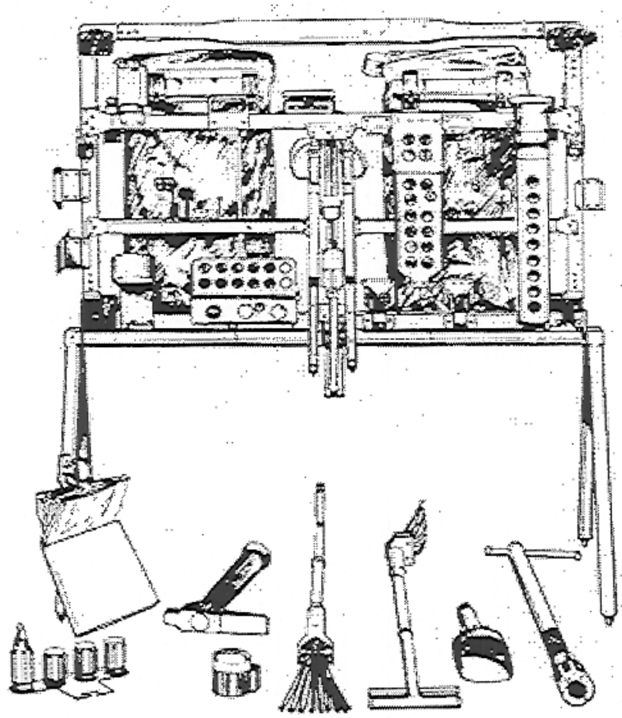

FIGURE 34.—Lunar Geological Hand Tools. This equipment is used to collect samples of rock and soil on the Moon. See text and subsequent figures for details.

Other tools used by the astronauts are shown in figure 34 together with an aluminum frame for carrying them. The hammer is used to drive core tubes into the soil, to break small pieces of rocks from larger ones, and in general for the same

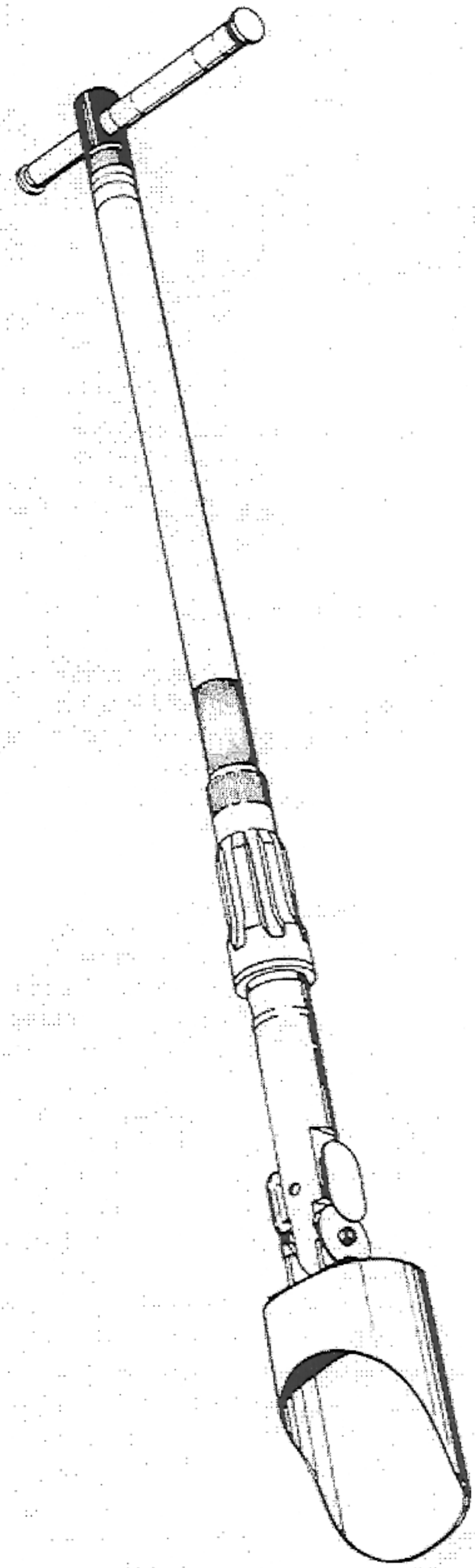

FIGURE 35.—Scoop with extension handle. Its use in Apollo 12 is shown in Figure 36.

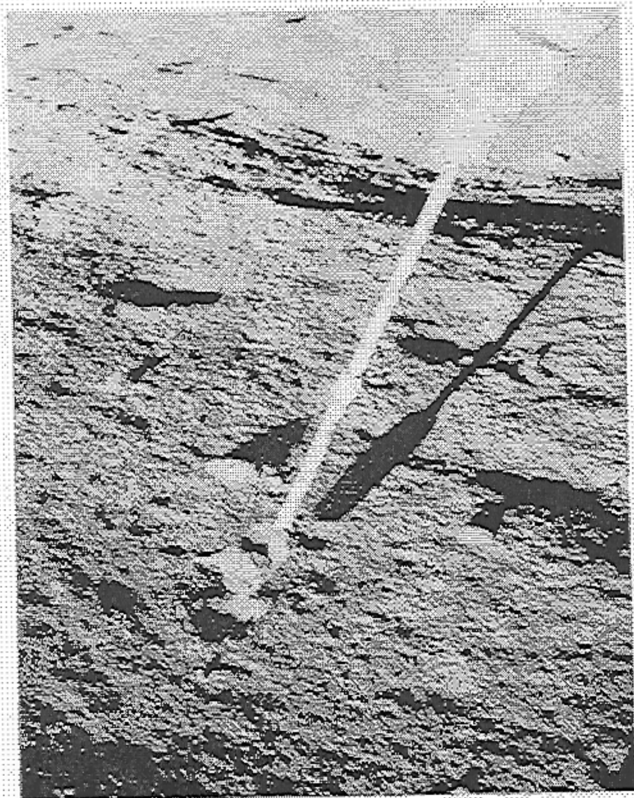

FIGURE 36.—Use of scoop in Apollo 12. Note the small rock in the scoop.

FIGURE 37.—Tongs shown in use on Apollo 12 to collect a small rock.

things that any hammer might be used on Earth. Because the astronaut cannot conveniently bend over and reach the lunar surface in his space suit, an extension handle is used with most tools. The scoop (figures 35 and 36) is used to collect lunar soil and occasionally small rocks. The tongs, sketched in figure 34 and shown in figure 37, an Apollo 12 photograph, are used to collect small rocks while standing erect.

The drive tubes (figure 38) are used to collect core material from the surface to depths of 1 to 4½ feet. The core remains in the tubes for return to Earth. Preservation of the relative depths of the core material is especially important. The drive tubes were originally suggested about 6 years ago by the late Dr. Hoover Mackin, a geologist. Shown in figure 39 is a drive tube that was driven into the Moon's surface on Apollo 14. The individual tubes are about 18 inches long. As many as three tubes can be used together for a total length of about 4½ feet.

After the surface samples are collected, they are placed in numbered sample bags made of Teflon (figure 40). These bags are about the size of the familiar kitchen storage bags. After a sample is bagged, the thin aluminum strip is folded to close the bag and prevent the samples from becoming mixed with others. The bags are finally placed in the sample return containers, sketched in figure 41, for return to Earth. The Apollo Lunar Sample Return Container (ALSRC) is about the size of a small suitcase. It is made of aluminum and holds 30 to 50 lbs. of samples.

A special container, termed Special Environmental Sample Container (SESC), is used to collect material on the surface of the Moon for specific purposes. (See figure 42.) This container has pressure seals to retain the extremely low pressures of the Moon. It is made of stainless steel. The sample to be collected on Apollo 15 and returned in this container will be collected in such a manner that it will have very little contamination with materials, either organic or inorganic, from Earth. The largest sources of biological contamination are the astronauts themselves; the suits leak many micro-organisms per minute and the lunar rocks collected on previous missions have all contained some organic material (a few parts per billion).

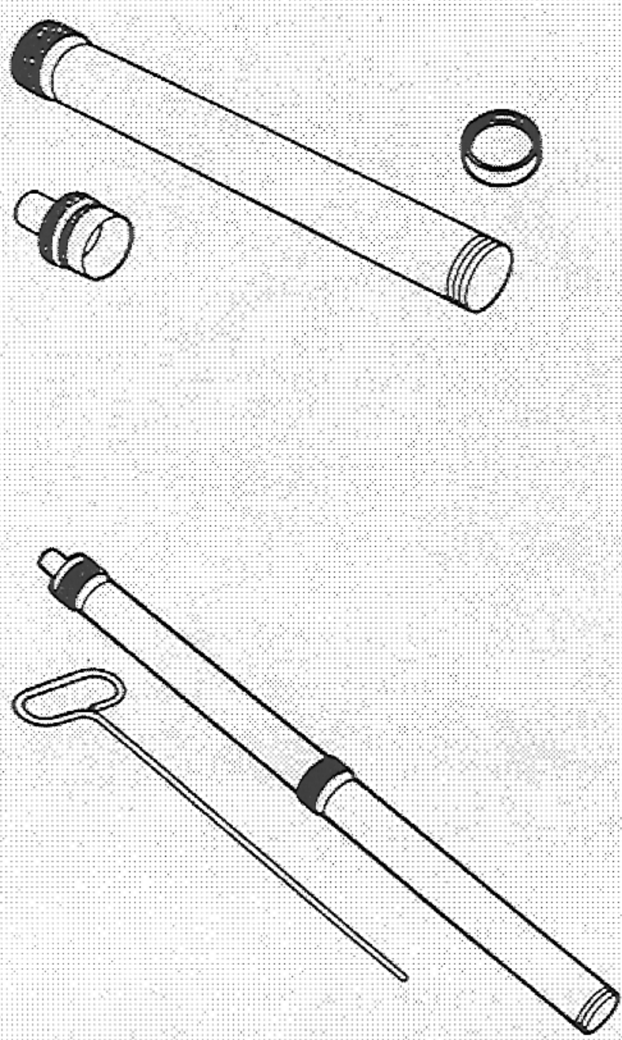

Figure 38.—Drive Tubes. These tubes, about 18 inches long, are pushed or driven into the lunar surface to collect samples as a function of depth. Two, three, or even four of them may be joined together to obtain a longer core. Their use in Apollo 14 may be seen in Figure 39.

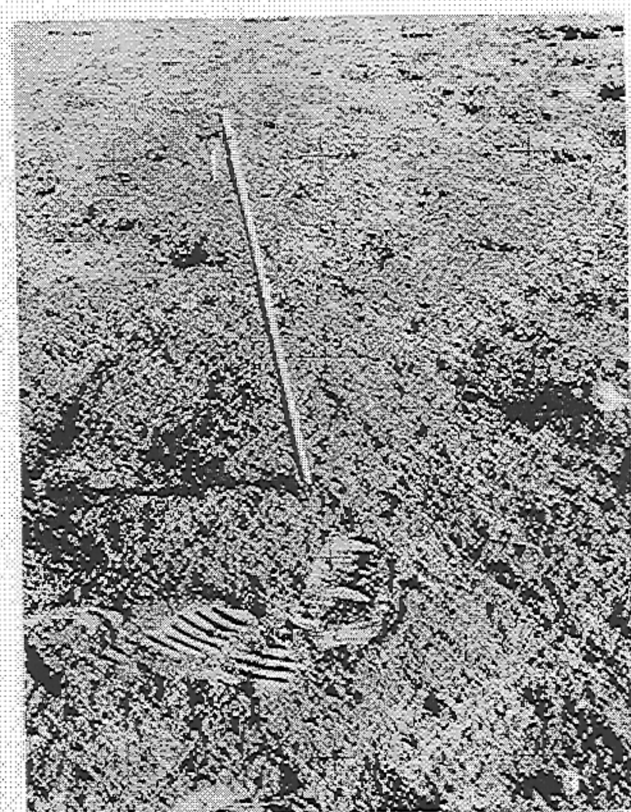

Figure 39.—Drive tube in lunar surface at Apollo 14 site. Note in addition the footprints, rocks, and small craters.

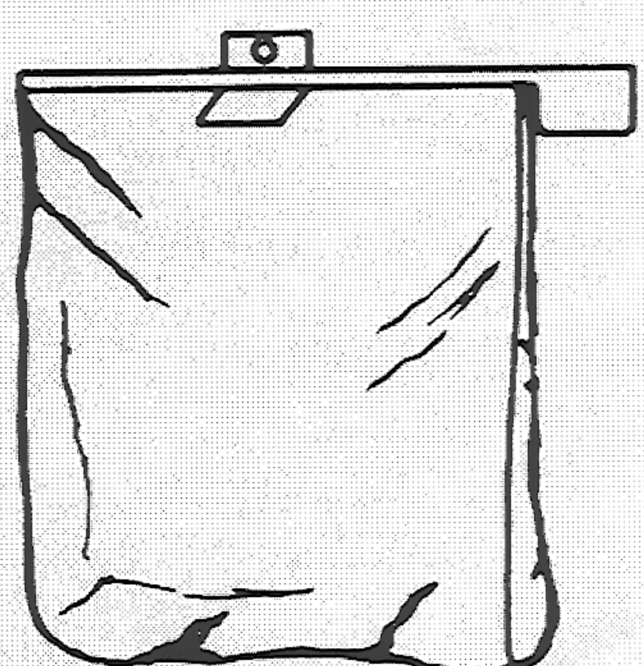

Figure 40.—Lunar sample bag. The bag resembles the familiar kitchen item "Baggies". It is made of Teflon. A strip of aluminum is used to close the bag.

Whether any of the organic material was present on the Moon before the astronauts' landing is uncertain; this question is currently being intensely investigated.

The Hasselblad cameras used by the astronauts (figure 43), were made especially for this use. The film is 70 mm wide, exactly twice as wide as the familiar 35 mm film. The color film is

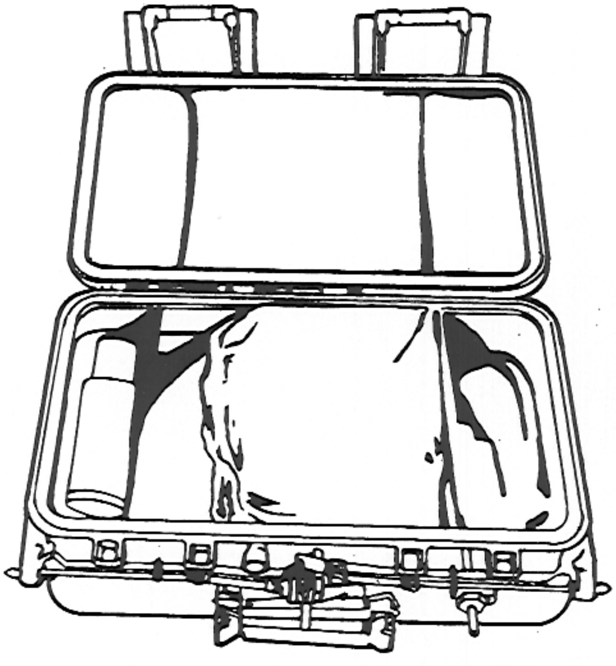

FIGURE 41.—Apollo Lunar Sample Return Container. Made of aluminum, this box is used to return lunar samples to Earth. It is about the size of a small suitcase but is many times stronger.

similar in characteristics to Ektachrome-EF daylight-type. The black and white film has characteristics like Plus X. The primary purpose of the cameras is that of documenting observations made by the astronauts. Especially important is the careful documentation of rocks that are collected for study back on Earth. Ideally, several photographs are taken of the rocks: (1) before collection with the Sun towards the astronaut's back, (2) before collection with the Sun to the side of the astronaut, (3) before collection a third photo to provide a stereo pair, and (4) after collection a single photo to permit us to see clearly which sample was collected. A device, termed gnomon and illustrated in figure 44, is included with these pictures to provide a scale with which to measure size and a calibration of the photometric properties of the Moon's surface. In addition to these photographs, a fifth one is desirable to show the general location of the sample with respect to recognizable features of the lunar surface. An example from Apollo 14 is seen in figure 45. The photos taken before collection and after collection show clearly which rock was removed.

At some stations, still more documentation is desirable. Panoramic views, also called pans, are obtained by shooting many photographs of the

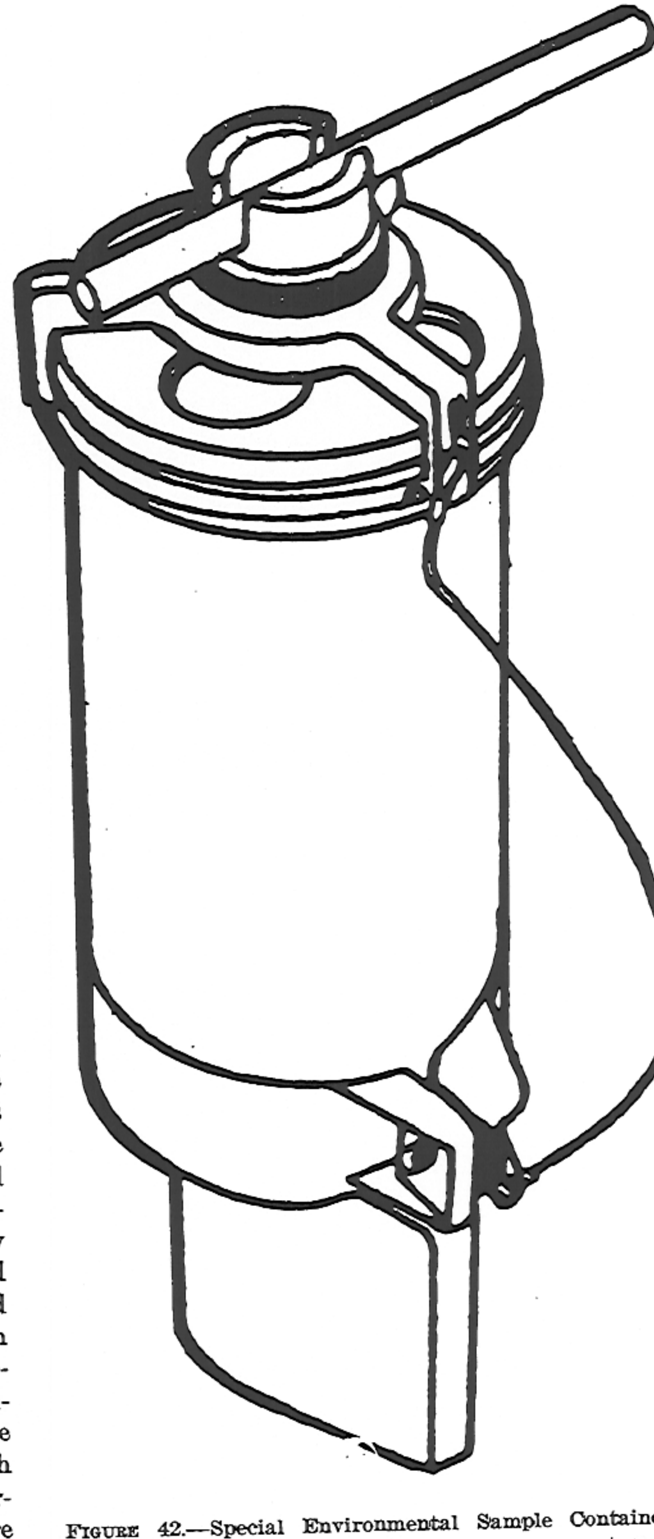

FIGURE 42.—Special Environmental Sample Container. This container has special vacuum seals to prevent gases and other materials from entering the container and being adsorbed on the surfaces during the journey to the Moon. They also prevent contamination of the samples by rocket exhaust gases and the Earth's atmosphere during the return journey.

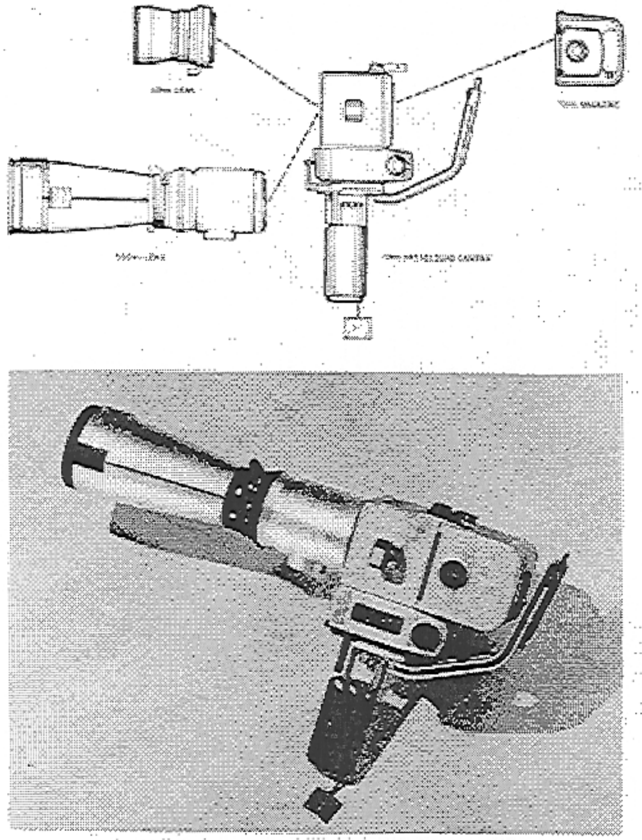

FIGURE 43.—Hasselblad camera. The film, which may be black and white or color, is 70 mm wide. Two separate lenses are used with this camera on the surface of the Moon. The 500 mm lens, a telephoto lens, shown attached to the camera in the photograph will be used to photograph the walls of Hadley Rille.

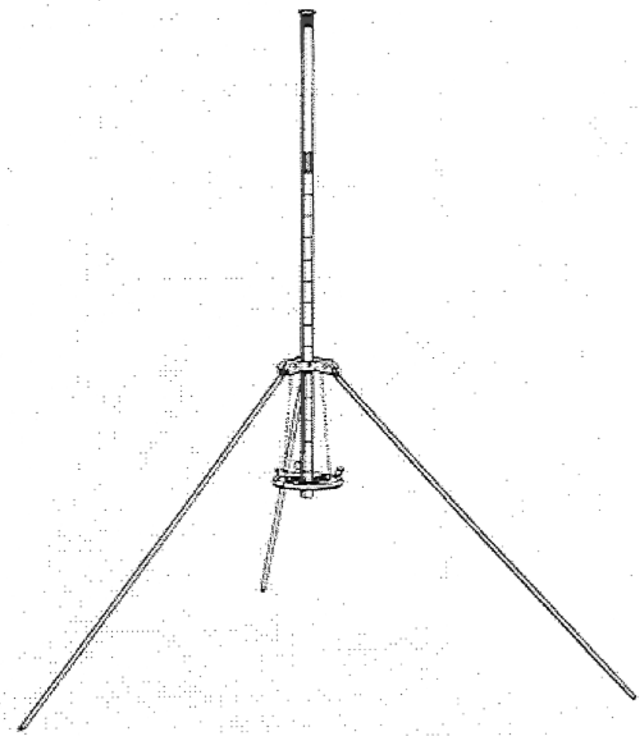

FIGURE 44.—Gnomon. This device is used to provide a physical scale and to calibrate the photometric properties of the samples on the Moon. It can also be seen in figure 45, an Apollo 14 photograph.

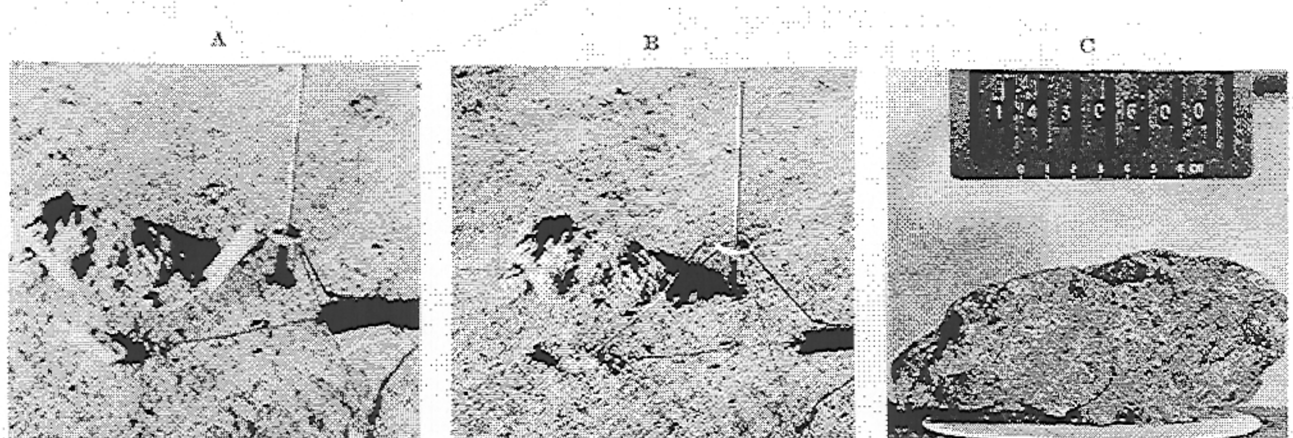

FIGURE 45.—Photographic documentation of lunar samples. These three Apollo 14 photographs indicate clearly the method used to identify the rocks that were collected. The shadows in A, together with knowledge of the time that the photo was taken, have been used to orient the specimen. A location photograph (not shown) allows us to determine the relative location of this sample with respect to others collected during the mission. Photo A was taken before the rock was collected. Photo B was taken after collection. Photo C was taken in the laboratory after the Apollo 14 mission had returned to Earth. The Field Geology Team, led by Dr. Gordon Swann, identified the rock in photos A and B as sample 14306 and deduced from photo A the orientation on the lunar surface.