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ABSTRACT

Man's second lunar landing, Apollo 12, provided a wealth of scientific information about the moon. The deployment of the magnetometer, seismometer, and ionosphere detector, and other activities on the lunar surface are described. A number of color photographs show the astronauts setting up equipment on the moon as well as close-ups of the lunar surface. Some illustrations are a full page in size. (PR)

Apollo 12

A New Vista for Lunar Science

Apollo 12

A New Vista for Lunar Science

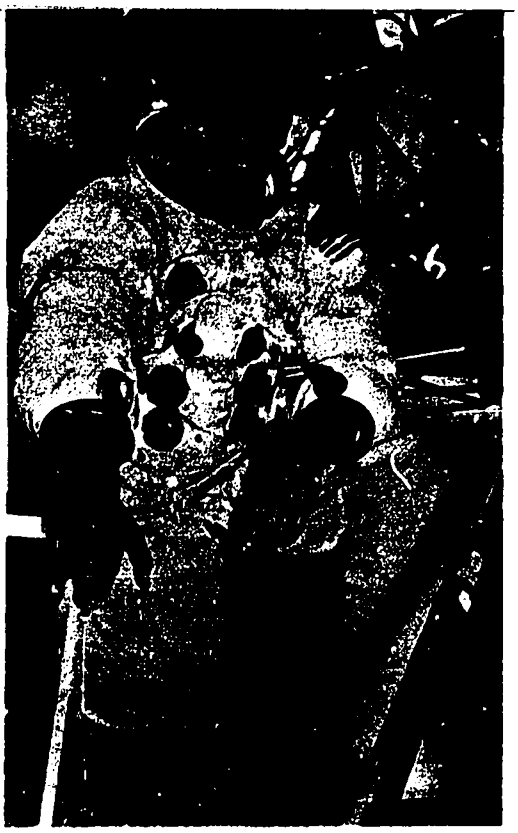
In reviewing the events of the 60's, historians will mark the year 1969 as the beginning of a new era in which the Apollo 11 flight demonstrated man's capability to leave Earth, land on another celestial body and return safely to his home planet. They will cite Apollo 12 as the beginning of a new era of different and, perhaps, more consequential dimensions when men took this new capacity and used it to achieve a broadening of the horizons of science.

A judgment of this kind was pointed out by one scientist soon after the completion of the Apollo 12 flight. He described the Apollo 12 mission as ". . . a thousand, maybe even a million times more important to science than Apollo 11." Director of the U.S. Geological Survey, Department of the Interior, W. T. Pecora, after a preliminary inspection of the lunar samples brought back by the Apollo 12 crew, commented that the rocks brought back by Apollo 11 were a ". . . geologic hors d'oeuvre" while the samples collected by Apollo 12 were ". . . a veritable feast."

If there was a constant in the early data produced by the Apollo 12 flight, it was the element of the unexpected. Experienced investigators, inherently cautious in drawing conclusions from data, particularly in the preliminary phases of analysis, inclined toward the view that basic concepts of lunar science would undergo major modifications as a result of the mission. The geophysical station, set up on the Moon's surface, has launched a new age in lunar studies and in the exploration of the solar system.

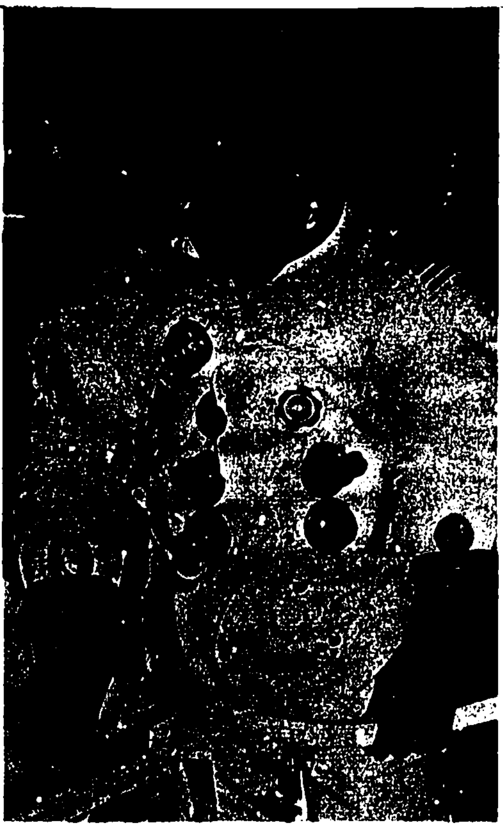
Important and exciting as the results of the individual experiments were, the broader implications of the mission were of greater significance. The new understandings of the dynamics of the lunar structure, its environment and the forces with which it interacts provide the basis for fresher and deeper insights into the origins of Earth, the forces that influence its environment, and its place in the solar system.

Deploying the Apollo Lunar Surface Experiments Package (ALSEP). On the extreme left are a carrying pallet and a gimbal cover. Moving from left to right are the Solar Wind Spectrometer, the Ionosphere Detector and the nuclear generator. The astronaut is standing next to the ALSEP Central Station with the Seismometer to his back and the Magnetometer in center foreground.



Captain Alan L. Bean, USN, Pilot of the **Intrepid** (the lunar module).

Captain Richard Gordon, USN, Pilot of the command module **Yankee Clipper**, who kept watch from lunar orbit while his crew mates walked on the Moon.



Spacecraft Commander Captain Charles Conrad, USN, who, along with Bean, won praise from the mission scientists for the work on the Moon.

Lift Off for the Ocean of Storms

As Apollo 12 lift-off time approached, a low overcast moved in over the launch area and rain fell. The question of delaying the launch was discussed and, after a search plane reported that there was no lightning within 20 miles of the launch pad, the mission directors elected to launch on schedule.

The countdown proceeded smoothly to ignition and then liftoff exactly as planned, and the huge Saturn V space vehicle cleared the gantry and climbed deliberately toward the overcast. As it entered the clouds, a bolt of lightning arced between the rocket and the ground. For a few heartstopping seconds there was silence, and then details started coming back from the Command Module (CM).

From the spacecraft: "Okay, we just lost the platform, gang. I don't know what happened here. We had everything in the world drop out . . . fuel cell, lights, and AC buss light, fuel cell disconnect, AC buss overload, one and two main buss A and B out . . ." The vital inertial platform, heart of the spacecraft guidance system, was "just drifting all over the place." Discussing the incident a few minutes later into the flight, the crew commented, "We all said there were so many trouble lights on we couldn't read them."

The flash triggered overload detectors and circuit breakers in the electrical systems into an automatic disconnect. This dropped the entire load on the backup battery system. In an emergency of this kind, this is what is supposed to happen.

Within roughly 3 minutes, the crew had closed the circuit breakers and overload detectors. All circuits were back in operation and the fuel cells again on-line. When the spacecraft entered Earth's shadow on its first orbit, Command Module Pilot Richard Gordon, took star sights and used the navigational fix, thus obtained to right the guidance platform.

Apollo 12 made a significant departure from the course followed by previous manned lunar missions. The three predecessor missions had flown a free return trajectory wherein, if the spacecraft failed to achieve lunar orbit, it would loop around the Moon and return to Earth. Apollo 12 was placed in a trajectory that lacked the free return factor. This was necessitated by the location of the landing site. Had a malfunction kept it out of lunar orbit, it would have swung into a highly elliptical Earth orbit that would have made its return to Earth far more complicated.

A significant feature of Apollo 12's lunar journey was its pinpoint landing 600 feet from Surveyor 3 (an unmanned spacecraft that landed on the Moon in April, 1967). Once set in the correct lunar orbit, the crew avoided activities, such as the dumping of wastes, that would have caused minor changes in its flight path. During the second phase of the landing maneuver, the powered descent, Spacecraft Commander Charles Conrad manipulated the on-board computer to compensate for errors that would have landed the Lunar Module (LM) 5 miles north of its target.

Establishing the capability for a pinpoint landing, a major objective of the mission, makes feasible the plans for future Apollo missions that are targeted for upland and mountainous areas of the Moon where rough terrain makes precise navigation essential.

The Saturn V Rocket boosts Apollo 12 toward the overcast.

Intrepid *readies for its powered descent to the lunar surface*

The Lunar Field Trips

Conrad starts down the ladder (attached to one of **Intrepid's** struts) toward the Moon's surface as Bean photographs him through the hatch.

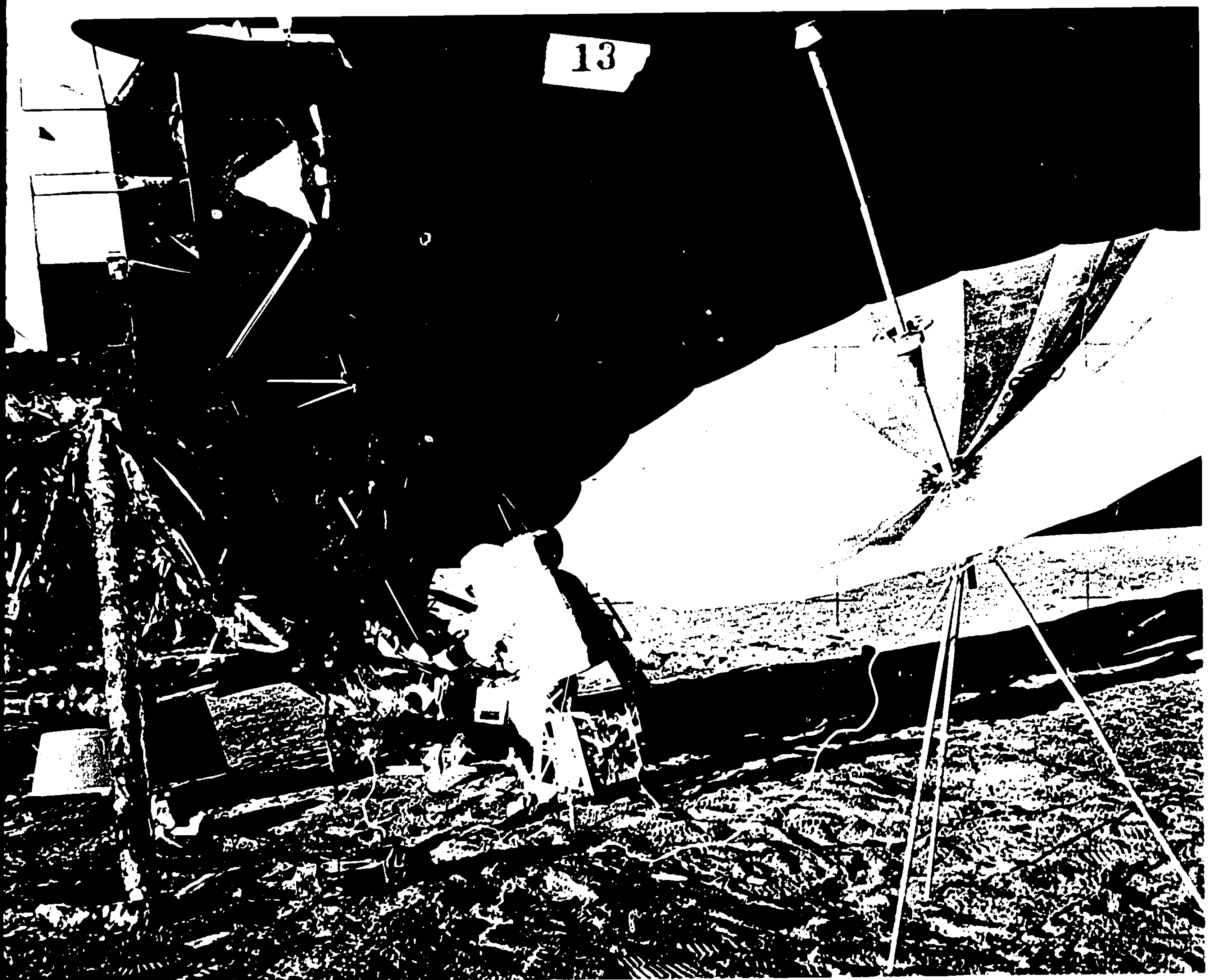
Seismoquakes

The ALSEP seismometer reported the descent of the LM and its violent return as well as the footsteps of the astronauts as they went about their lunar duties. Within a short time after its deployment, it had recorded ten events of natural origin which lasted from 20 to 40 minutes—probably micrometeorite hits—although as one experimenter put it, no self-respecting geologist would have said so before the Apollo 12 mission. As lunar night fell, the thin layer of igneous mantle rocks—called a regolith—that underlies the maria in the vicinity of the Apollo 12 landing site was twisted and tilted by the rapid drop in temperature. The seismometer recorded this geologic unrest.

This instrument which was unveiling the mysteries of the Moon's internal structure is perhaps as remarkable as the data it transmitted. As part of a geophysical station that has no peer on the Moon—or on Earth—the seismometer is a marvel of compactness and sensitivity. Equivalent instruments in Earth-based observatories would be ten times larger. The ALSEP instrument is 16" high and weighs 20 pounds. It is so sensitive that it would be useless on the dynamic and quake-ridden Earth. Wind and wave motion alone would dominate the instrument. It is "critically damped" so that there is no resonance. A shock is recorded once and the sensor is instantly ready to record the next one.

The geological survey conducted by the two astronauts occupied a small fraction of the first walk on the Moon's surface and most of the second walk. Geologists at the Manned Spacecraft Center at Houston were delighted with the performance of their exuberant proxies on the Moon's surface. The running commentary maintained by Conrad and Lunar Module Pilot Alan L. Bean enabled the scientists to determine that the assigned tasks were properly executed and also provided on-the-spot observations that could be linked to specific locations and particular samples that the astronauts were collecting. One geologist described the astronauts as "real rockhounds": high praise from a professional.

Intrepid, as the LM was named, landed some 25 feet from the rim of the crater containing Surveyor. Conrad described the surrounding area as "sort of like an undulating plain." "I'm sure,"



An astronaut prepares an ALSEP experiment for movement to the site where it will be set up. At right, the S-band dish antenna.

he said, "that some of these rocks have different colors and different textures, but from here in the spacecraft . . . they all appear to be of the same material and they all appear to be pure white." Subsequently, while on the second walk, both Conrad and Bean were to report grey, tan and brown tones which they tentatively linked to the Sun's angle of elevation and whether they were looking down-Sun or across it.

They reported rock-rimmed craters of varying sizes in almost every direction. Some of the boulders were very large, on the order of 20 feet. They also noted what they suspected was bedrock.

Conrad was first out of the LM and began his chores with an ebullience that was to characterize the actions of both astronauts throughout their time on the lunar surface. The first moments outside were spent getting acclimated to a lunar gravity one-sixth that of Earth's. Conrad commented: "I have the distinct impression I don't want to move too rapidly. But I can walk quite well."

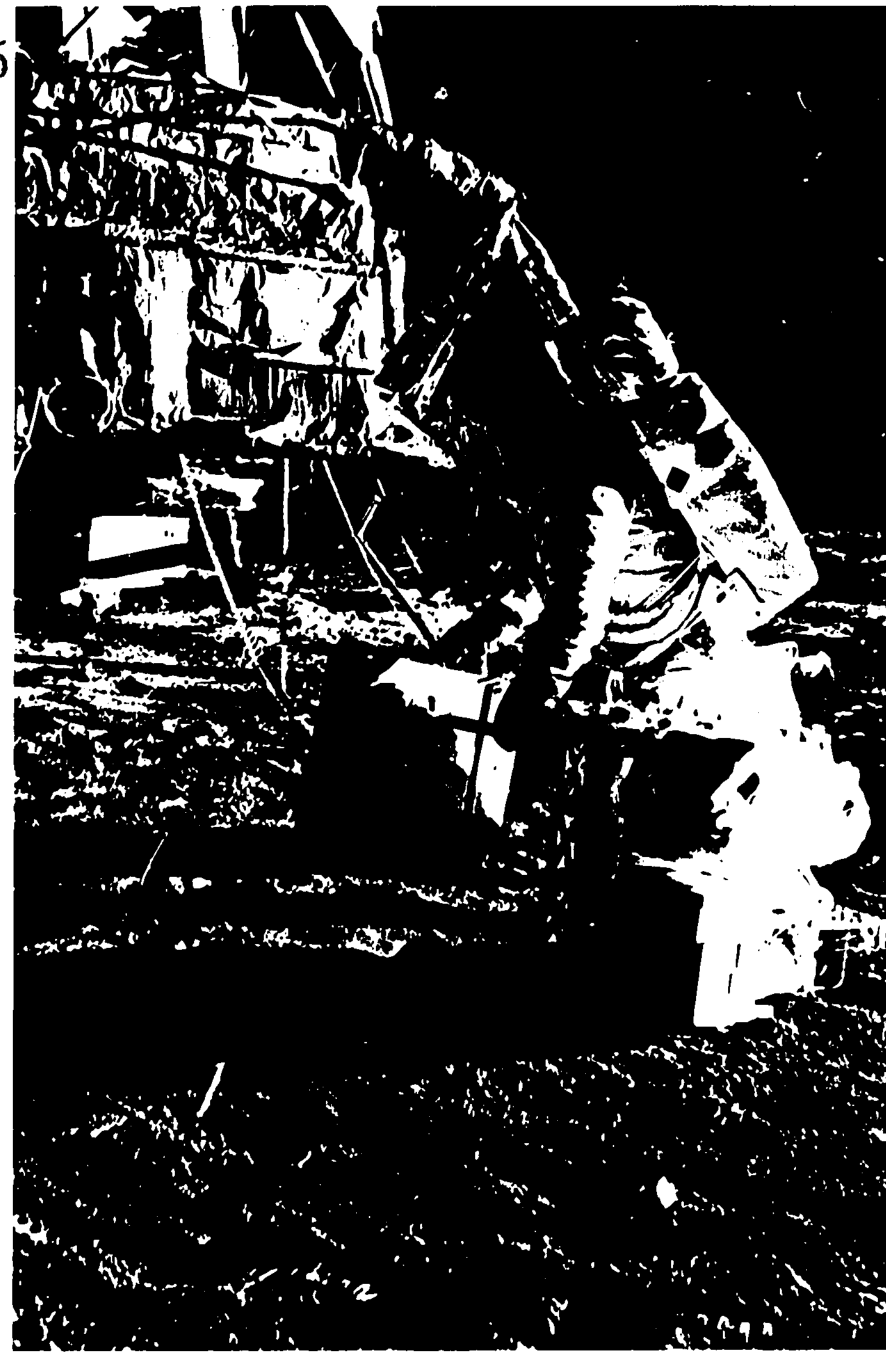
After an exchange with Houston, Bean told Conrad, "Boy, you sure lean forward." Conrad rejoined, ". . . don't think you're gonna steam around here quite as fast as you thought you were."

The powder-like dust on the Moon's surface that was to plague the astronauts throughout both their walks was quickly evident. It eddied in a thick cloud below the LM as the spacecraft approached the lunar surface, forcing Conrad to land on instruments. As Conrad took his first steps on the Moon, Bean told him, ". . . your boots are digging in the soil quite a bit . . . your left foot has a big mound ahead of it right now just pushing along." As they unloaded the LM with the pulley arrangement, both reported they were getting dirty. The dust quickly coated the ALSEP (Apollo Lunar Surface Experiments Package) instruments even as they were being deployed. One astronaut commented, "There's no way to handle all this equipment with all the dust on it. Every time you move something the dust flies . . . goes way up in the air and comes in and lands on you."

Conrad's first task was collecting the contingency sample, a bagful of black soil. With Bean assisting he undertook to deploy the S-band antenna, a dish-shaped device to augment their radio signal strength, and encountered the first of a sequence of minor problems with their equipment. They had trouble getting the antenna into a stable position and finally resolved the matter by pushing the legs of the supporting tripod into the lunar surface.

After planting the American flag, the astronauts set about deploying

Bean lifts the hot plutonium core, sheathed in its cask, from its place of storage aboard the ***Intrepid.*** *The generator is in the foreground.*



Assembling the ALSEP instruments on the bar-bell preparatory to carrying them to the deployment site.

Surface Magnetometer

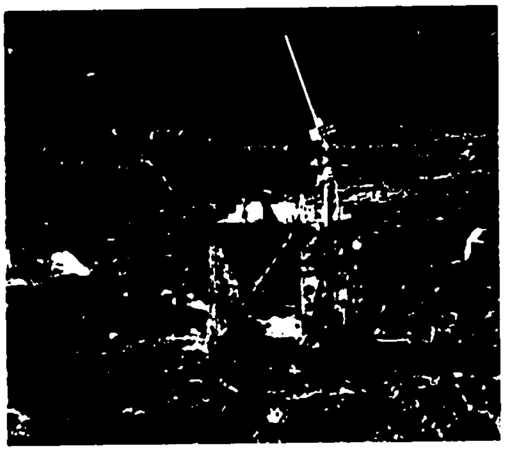
A component of the ALSEP that returned unexpected information was the surface magnetometer, designed to determine if there was a lunar magnetic field and, if so, to measure it.
The instrument also provided data on the electromagnetic disturbances created by the solar wind. In addition to the light it gives out, the Sun radiates vast quantities of ionized particles of energy spun out into space at tremendous velocities. This "wind" also contains magnetic fields that geophysicists want to measure. Finally, besides its electromagnetic effect, the extent to which the solar wind penetrates the Moon will assist in determining the Moon's composition.

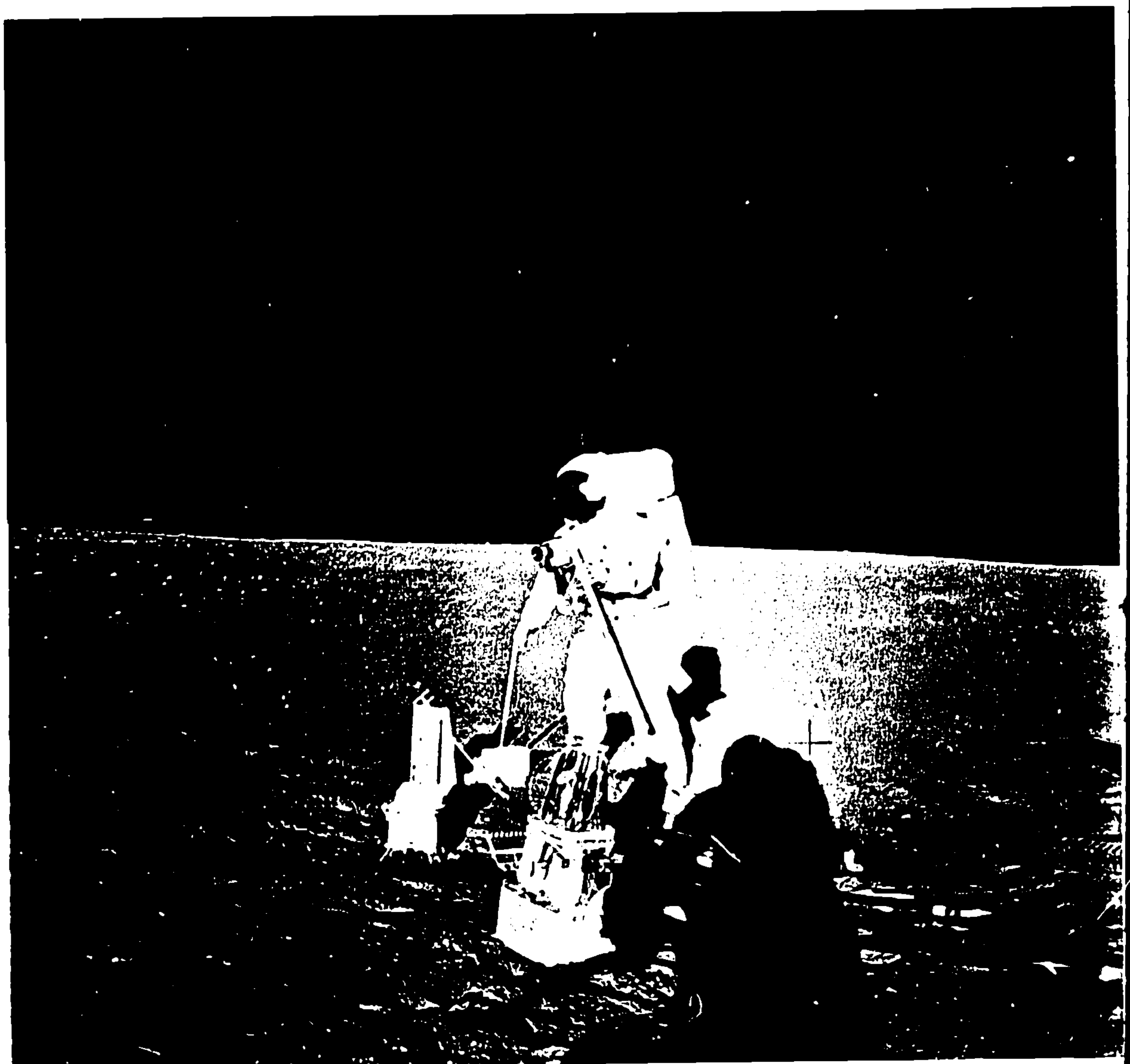
The magnetometer recorded a magnetic field with its focus 600 feet from the instrument—a distance that could be either vertical or lateral. This field could extend over half the Moon's surface. Though very weak, the magnetometer reported it at least four times stronger than that recorded by the Explorer satellite IMP (for Interplanetary Monitoring Platform) from its orbit above the Moon. The IMP read the field strength at 5 gamma while the surface magnetometer set the level at between 20 and 30 gamma. For purposes of comparison, Earth's magnetic field is 25,000 gamma. The new data suggests that the Moon's magnetic field is close to the lunar surface [illegible] of feet—and perhaps a [illegible] of the lunar structure. It is possible that it is held to this low altitude by the force of the solar wind.

Early in its period of operation, the magnetometer passed through the bow shock wave which is created by the encounter of the solar wind with Earth's geomagnetic tail. This wave and an adjacent area of turbulence on the side of the wave away from the solar wind are of particular interest to scientists. As it passed through the bow shock, the instrument recorded three separate "bounces" with values of 90 gamma, 120 gamma and [illegible] gamma, the highest ever recorded in the vicinity of the Moon. These "bounces" lasted approximately 3 minutes and were several hours apart. They could have been caused by fluctuations in the bow shock striking the magnetometer at random or could be attributed to solar flares.

The magnetometer (center foreground) which provided new data on the Moon's magnetic field.

The Central Station of the ALSEP distributes the power generated by the SNAP 27. The station also transmits data to Earth and receives commands from Earth.





Astronaut working at the ALSEP site.

Like the solar wind, the penetration these relatively strong impulses achieve into the Moon provides information on its structure. When the Moon's orbit swung the sensor clear of Earth's magnetic tail, readings dropped to 40 gamma, which was construed to be a combination of the effect of the Moon's internal field of 30 gamma and a solar wind field of approximately 10 gamma. It will require another magnetometer at a different landing site to resolve the question of fundamental importance: i.e., whether the field is a property of the whole Moon or merely of an area of the Moon. Experimenters believe that readings from three complete 28-day lunar cycles will be needed before reliable average values are established.

(continued from page 5)

the powered instruments of the ALSEP. They selected a spot about 600 feet northwest of the LM on the far side of a small crater. This was so the instruments would not be disturbed by the blast of the LM's ascent engine on lift-off from the Moon.

The deployment was not without difficulties. Despite the astronauts' initial efforts, the Lunar Atmosphere Detector toppled over on its side and the aluminum skirt of the seismometer persisted in curling up at the edges as a result of it having remained so long in the rolled state in which it was packed. The astronauts finally got the detector to remain upright and a suggestion from Houston—to weight the edges of the skirt down with some lunar dirt—flattened the curl. Once they had pulled the plutonium core out of its cask and inserted it into the power center, three of the instruments began operating immediately.

The astronauts continued in a northwesterly direction from the ALSEP passing within a few feet of *Shelf* crater, a feature about 1,000 feet in diameter with large boulders in its basin. They told Houston, "... we're looking down at this big crater and it looks rather old and it has bedrock at the bottom . . . there are some big boulders resting inside the rim . . . we don't see any outcrop of rocks either . . . say, well, from the top of the rim down to about 20 feet." They passed some small, very fresh craters as well.

For the return trip, they made a "U" turn and came back toward the LM on a course parallel to, and east of, their outward track. They passed a mound that caused Bean to exclaim: "I don't know, Houston, what they are. They're just sort of mounds." After warning Houston not to take the following comment the wrong way, he said, "It looks like a small volcano only its just about 4 feet high and about 5 feet

One of two mounds reported by Bean, a feature that puzzled the geologists.

The everpresent lunar dust, caught by the Sun's rays, a halo for an astronaut.

across at the top. It slopes down to a base with a diameter of 15 to 20 feet."

There were two such mounds—the only two in the entire area of their walk or in the area they could cover visually. Geologists on the ground speculated that they were piles of coarse materials ejected from a crater. The astronauts spotted a block too large for the tongs, so one pushed it over to the other who picked it up and stowed it in his sample bag.

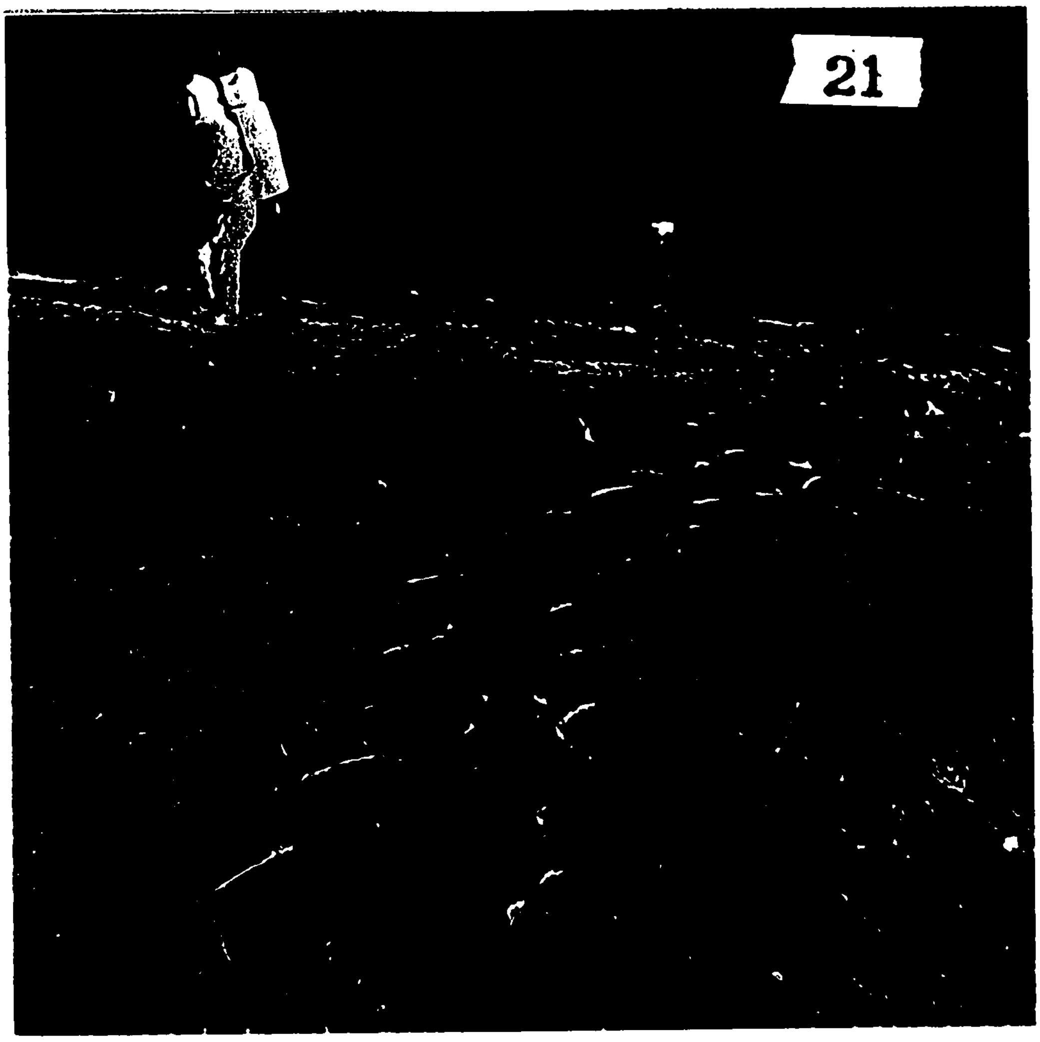
Under instructions to return to the LM for rest, the two astronauts set out for the spacecraft, stopping at intervals to pick up rocks that looked interesting after photographing them in place. One of these Conrad described as a "pure piece of glass."

On reaching the vicinity of the LM, Bean sank the core tube some 32 inches into the lunar surface, 20 inches deeper than the Apollo 11 crew had been able to penetrate and with less resistance.

When Conrad's time on the surface reached 3 hours and 38 minutes, Houston advised that they had a fair amount of consumables remaining and not to rush too hard to get back into the spacecraft. The crew did their housekeeping, stowed their rock collections and the core sample. They also attempted to clean up. "Man, are we filthy. We need . . . a whisk broom." Then Conrad to Bean, "Dust me off and I'll dust you off and we'll get in."

The Power Center

The instruments making up the ALSEP got power from a central source unique in space history: a SNAP 27—for Space Nuclear Auxiliary Power. SNAP 27 is fueled by a rod of uranium 238. Removing the rod from its cask, and inserting it into the power unit was perhaps the astronauts' most ticklish assignment of the mission. Extraordinary precautions had been taken to prevent a slip or mishandling which would have had serious consequences. When the astronauts attempted to extract the rod from the shielded cask, it stuck. After repeated blows on the cask with a hammer, the rod was freed, withdrawn from its container, and inserted into the power unit without further difficulty. The unit is generating 73.59 watts of electric power, higher than the design output. It has an operating life of at least 2 years.



A trail of footprints on the lunar surface. Object in the background is the color television camera that was thought to be sunstruck early in the first of 12's two Moon walks.

The Long Traverse

Lunar Atmosphere Detector

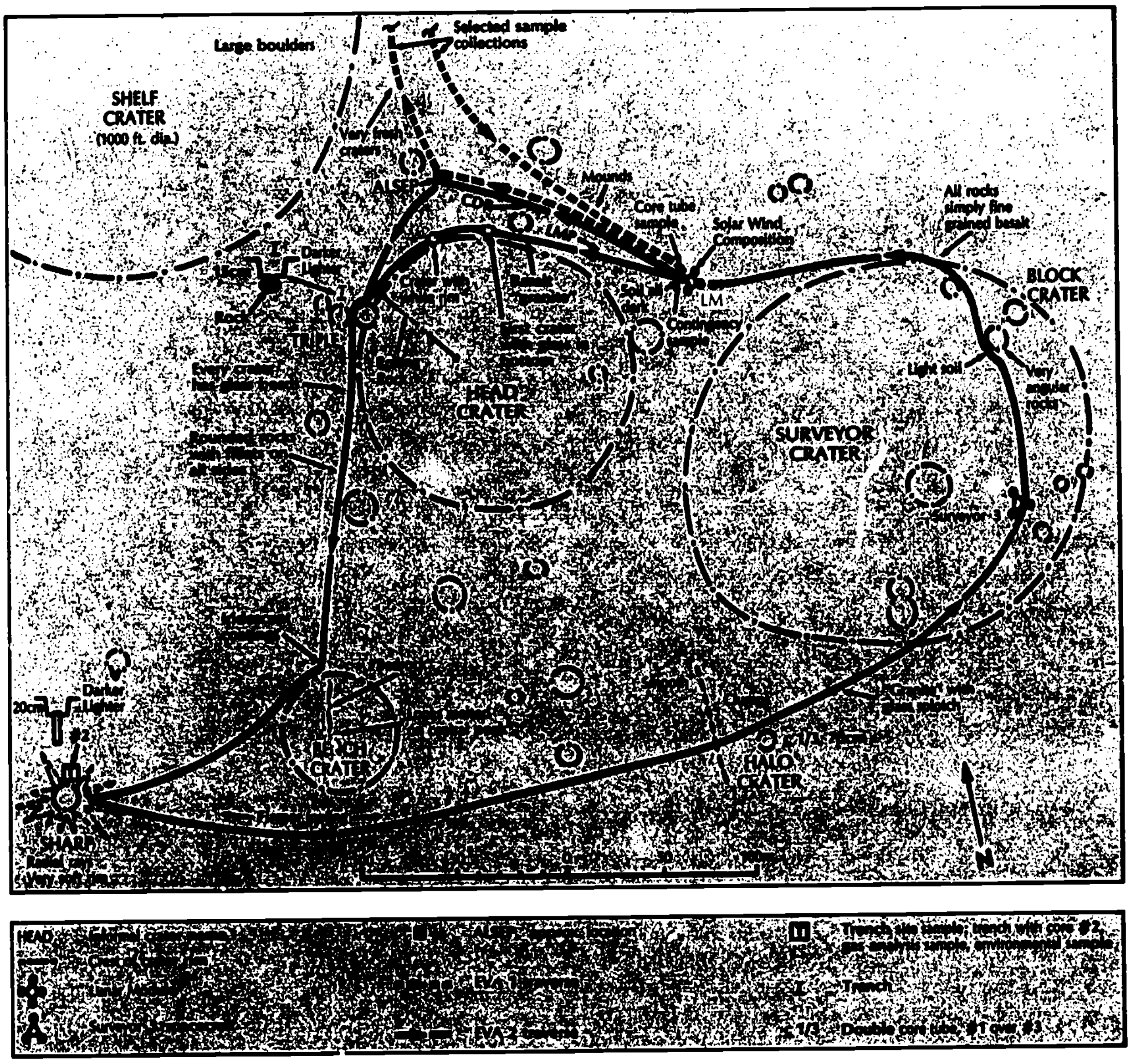
This instrument, which was designed to measure the density of the very attenuated lunar atmosphere, was turned on between the first and second walks of the Apollo 12 crew. A highly sensitive instrument, its maximum reading is for an atmosphere with a density one-millionth that of Earth.
For reasons that are not clear, the instrument ceased functioning during the second Moon walk and did not respond to turn-on commands. Astronaut Conrad passed it during his walk and it is possible that the discharge of gas from his suit material overloaded the sensor.

After a 5 hour sleep and a conference with Houston about the long traverse planned for the second Moon walk, Conrad and Bean were ready to return to the lunar surface. The traverse had been carefully plotted so as to bring the astronauts to local features with a special potential for scientific finds. They were to leave the LM and skirt the northern rim of *Head* crater — one of the *Snowman* group. After reaching the western side, they were to pass between the inner pair of three small craters and proceed nearly due south to *Bench* crater. From there they would swing west-by-south to the small crater, *Sharp*.

Next objective was *Halo* crater, a small feature close to the southern rim of the crater in which Surveyor lay, east and north of *Sharp*. Their route would then take them into Surveyor crater and over to the Surveyor spacecraft for inspection of the hardware and the removal of selected components so that these could be examined, on return to Earth, for the effects of a 31-month exposure to the lunar environment. They would then exit from the Surveyor crater and travel west to the LM.

Conrad began his observations while still in the spacecraft. "The material around the spacecraft . . . looking into the Sun . . . a very rich brown color like a good plowed field . . . down-Sun, it is still the same ash grey." He called attention to a 3½-inch rock sitting, loose, 6 inches from the engine bell of the LM that had not been blown away by the engine exhaust although the ground around it had been swept "glassy clean."

En route to *Head* crater, at Houston's request, the solar wind composition experiment was photographed. Not a part of the ALSEP powered unit, this was a strip of foil-like material shaped like a window shade designed to trap gas particles in the solar wind.



Map of both walks taken by the astronauts. The large central and right-hand craters form the head and body of the "Snowman." The name is informal as are the names given the individual craters. The second walk was approximately a mile long.

The device had been set up early in the first walk to give it maximum exposure. The astronauts had reported during the previous walk that it had bent back around its supporting staff as though actually blown by a wind. A close-up inspection revealed the effect to be an optical illusion.

While Conrad was checking the ALSEP, Bean found a "dandy extra grapefruit-size rock." After making sure that Bean was standing still to prevent his movements from registering on the seismometer, Conrad rolled the rock down the slope of *Head* crater. "It's strike down, hit, hit, hit. Now it's just rolling . . . roll, roll, roll." Houston told the astronauts that the bouncing rock had registered on the seismograph. Other observers doubted that there had been a significant return of data.

Conrad spotted a rock with small crystals, one "shining very, very bright and clean like a ginger ale bottle." Bean told Houston that a crater, about three feet in diameter, on the rim of *Head* crater, had glass beads on its floor and glass-coated rock fragments. He speculated that the crater "was made by a not very fast moving or energetic or heavy projectile." He collected samples of the materials. He described to Houston "nice white small craters with white rims."

Both astronauts busied themselves taking pictures of the phenomena they observed. In the terrain west of *Head* crater, Conrad kicked the dark surface layer with his boot and uncovered lighter, cement-colored soil underneath. The development prompted the astronauts to trench the area, and they found lighter-colored, grainier material markedly different from the surface layer. Bean took samples from the bottom of the trench and stored them in a special container which preserved the lunar environment in which the rock was found.

Locomotion in gravity 1/6th that of Earth. An astronaut gets on his toes to begin a lunar "lope."

A close-up of the Solar Wind Spectrometer which is measuring the energies of the particles that make up the solar "wind." A vast flow of these particles is spun off by the Sun at very high velocities. The experiment has sent good data from the outset and its readings have been consistent with those of the magnetometer.

A second Solar Wind experiment. This sheet of foil-like material was set up by Conrad, shortly after leaving **Intrepid,** to trap particles in the "wind." In eighteen hours of exposure, it confirmed that a thin, high-velocity "wind" blows across the lunar surface. Each square centimeter of the foil was peppered with between six and seven million atoms each second.

The Seismometer which recorded **Intrepid's** crash landing on the Moon, and other natural lunar events.

The astronauts began a trek southward, picking up samples as they went. They commented that every crater contained the glass beads and described rounded rocks with skirts of surface dust on all sides. On approaching *Bench* crater, Conrad stated that it was very different from *Head* crater, with what looked like bedrock on its floor and material that appeared to have been melted. Bean thought the tiny central peak in the crater also had a melted appearance. Near the rim of *Bench* crater, the astronauts encountered rocks with an iridescent coating and others that were splattered with glass.

The astronauts walked west about 400 feet to *Sharp* crater which was small enough to raise doubts that they had located the right feature. *Sharp* had a white rim, raised about 2 feet, of much softer material than had previously been encountered. Surrounding the rater was a radial pattern of rays. ean trenched the area to a depth of 8 inches and they took samples. Conrad then took a core tube sample from the bottom of the trench.

Houston transmitted directions to *Halo* crater, the next stop. As the astronauts passed south of *Bench* crater, they reported firmer footing. Bean said that, as he pushed off, the toes of his boots sank in about 3 inches, but on landing flatfooted, the heels sank in only 1/8 of an inch. Conrad commented that in moving he felt like a giraffe running in slow motion. Bean told Houston that he got the "decided feeling" he was going to sleep that night, and that he could go for a good drink of ice water.

Surface material in the vicinity of *Halo* crater differed from the smooth top layer over which the astronauts had been walking. Bean described it as "more cohesive . . . in clumps." They took a double core tube sample, using the hammer to drive the tube its full 32-inch length into the soil. One rock that caught Conrad's eye looked like "granite" (it wasn't) and had a large glass splotch on it.

In collecting samples, Bean devised a means to make leaning over and picking up a rock easier. By grasping a strap on Conrad's backpack and steadying him as he bent over, Bean compensated for the awkwardness resulting from the rigidity of the pressurized spacesuits and the difficulties with balance in a low-gravity environment. Conrad advised Houston that he had yet to

An astronaut forces the core tube into the lunar surface to obtain subsurface samples of lunar material.

The tongs used to help the astronauts pick up lunar rocks.

Ionosphere Detector

The Ionosphere Detector, which measures the lunar ionosphere, was inadvertently activated on November 19th when the dust covers were opened during deployment. It returned interesting and useful scientific data. Some outgassing took place that caused arcing which does no damage to the instrument, but prevents it from transmitting data. Experimenters turned the instrument off until it had purged itself of its gases. The interval also allowed time for the LM, which burps and grunts like an overfed puppy for several days and thus muddles the data coming from the sensors, to do likewise. The sensor was commanded back into operation in early December and has operated successfully since. In its early stages the background data rate was extremely low. This changed when the Moon's course brought the instrument back into sunlight.

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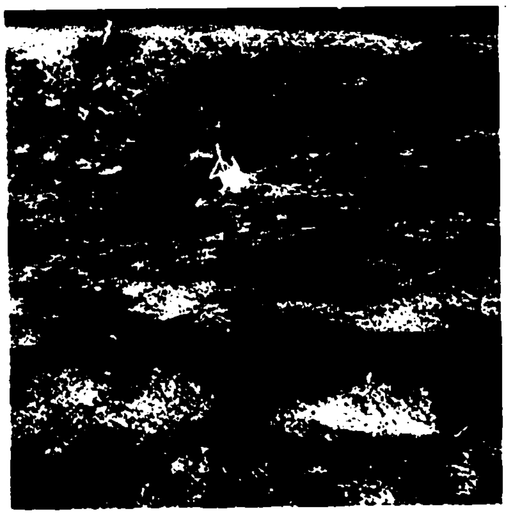
see any of the breccia — differing mineral fragments in a binder of another kind of rock—that predominated the samples brought back by the Apollo 11 crew. Bean added, "This is not at all like Neil's run."

The astronauts crossed the southern rim of Surveyor crater and followed the approximate contour line on which Surveyor 3 rested, a curving path parallel to the rim. They told Houston they weren't sinking very far, that the surface was "fairly firm stuff." They continued around the rim toward the prize that their precision landing had won them—Surveyor. The spacecraft had bounced after touchdown and the impressions made by its footpads at first contact with the surface were carefully photographed.

Conrad mentioned the brownish tint of Surveyor and learned from Houston that, originally, the equipment bays, the primary structure, and the struts were white. A closer inspection revealed that the spacecraft had taken on a coat of the everpresent dust. The mirror used in Surveyor's photo system had not cracked, but was slightly warped and was covered with a fine coating of dust. Bean rubbed it with a piece of cloth attached to his wrist and some of the coating came off. Scientists are curious whether the dust accumulated over a period of time or whether it was blown on the spacecraft by the landing of the LM.



View of Surveyor 3 from **Intrepid**.

An astronaut prepares to cut off Surveyor's trenching scoop to return it to Earth for analysis.

Approaching Surveyor from the southeast with **Intrepid** *in the background.*

Surveyor footpad next to imprints left by its initial touchdowns. Imprints appear fresh despite 31 months of exposure to the lunar environment.

Conrad and Bean unlimbered a cutting tool and snipped off two pieces of tubing—one painted and the other unpainted. A tube that they had been assigned to get proved too thick and tough for the tool so they cut another. They also cut off a length of cable, the Surveyor's trenching scoop, and the spacecraft's camera. With these pieces of salvage, a laboratory examination would reveal how the various coatings reacted to prolonged exposure to the Moon's environment. The camera would show how electrical, mechanical and solid state components and the thermal control coating had been affected. All the parts would be checked for chemical properties and the scoop given a microbiological examination. While at Surveyor, the astronauts completed a photo assignment and filled a bag full of samples.

Block crater, an impact feature within the larger Surveyor crater, was described as "fantastically interesting," with a lot of bedrock in it and big, chunky rocks with sharp corners blown up out of it.

On the way back to the LM, the astronauts collected additional samples and took more pictures. Among the last of the photos was the area under the engine of the LM that had been swept clean of dust by the engine exhaust.

The astronauts' experience in working on the lunar surface will make the Moon walks of their successors easier and more efficient. Both Bean and Conrad were critical of some of the equipment with which they had to work. On several occasions, Bean commented on difficulties with the rock bags and noted the need for sturdier construction. They had to make a quick fix on a set of scales and they were less than pleased with the tool carrier. Houston made note of the problems with their hand cameras, and the difficulties in stabilizing ALSEP instruments will be the subject of study before the next Apollo launch. It may well be that Bean's method of dealing with the uncertainty of balance while leaning over will result in future spacesuits coming equipped with a handle on the back that a partner can hold while the astronaut bends.

Yankee Clipper *photographed from the* **Intrepid** *as it approaches for docking*

Rejoining Yankee Clipper

One of the critical maneuvers in a lunar mission, where there is no recourse from an engine failure, is the ascent from the lunar surface to rendezvous with the mother ship. The LM's designers entrusted the task of boosting it back into lunar orbit to the ascent engine of the LM's upper stage, a constant-thrust rocket engine that engineers have described as one of the world's most beautifully simple examples of engineering design. Except for the bell-shaped nozzle, every component of significance has a backup ready to take over in case it fails.

After an intensive checkout of the systems of the upper stage, and a lengthy exchange of situation checks with Houston, *Intrepid* radioed, "The engine is fired." During the seconds following, *Intrepid* transmitted a series of staccato reports on the ascent.

"It's good."

"Pitchover looking good."

Thirty seconds after liftoff they were 1,594 feet above the lunar surface.

"We're on our way. This program looks good. Keeping right down the pike. What a nice ride."

At 4 minutes and 8 seconds they were travelling at 2,400 feet per second relative to the Moon, and gaining speed. Seven minutes after lift-off, velocity had built to 5,000 feet per second. Seconds later, the crew shut off the engine. *Intrepid* had achieved lunar orbit.

As they started their catch-up maneuvers with *Yankee Clipper*, Conrad told Houston, "I sure do enjoy flying this thing." *Intrepid* and *Yankee Clipper* steadily cut the distance separating them from 140 miles, to 80 miles and finally from *Yankee Clipper*, "Hey, Pete, I've got you at 6/10 of a mile. How can you look so good if you're so ugly?"

Intrepid: "I don't know. You look awfully good yourself."

Shortly after this exchange the two spacecraft were station keeping; and began the cautious, creeping final approach. Finally, from *Yankee Clipper*, the active member in the docking maneuver, ". . . and you're home free boys." *Intrepid* responded, "Super job you did. That was cool, wasn't even a ripple."

Yankee Clipper and *Intrepid* were firmly joined once more.

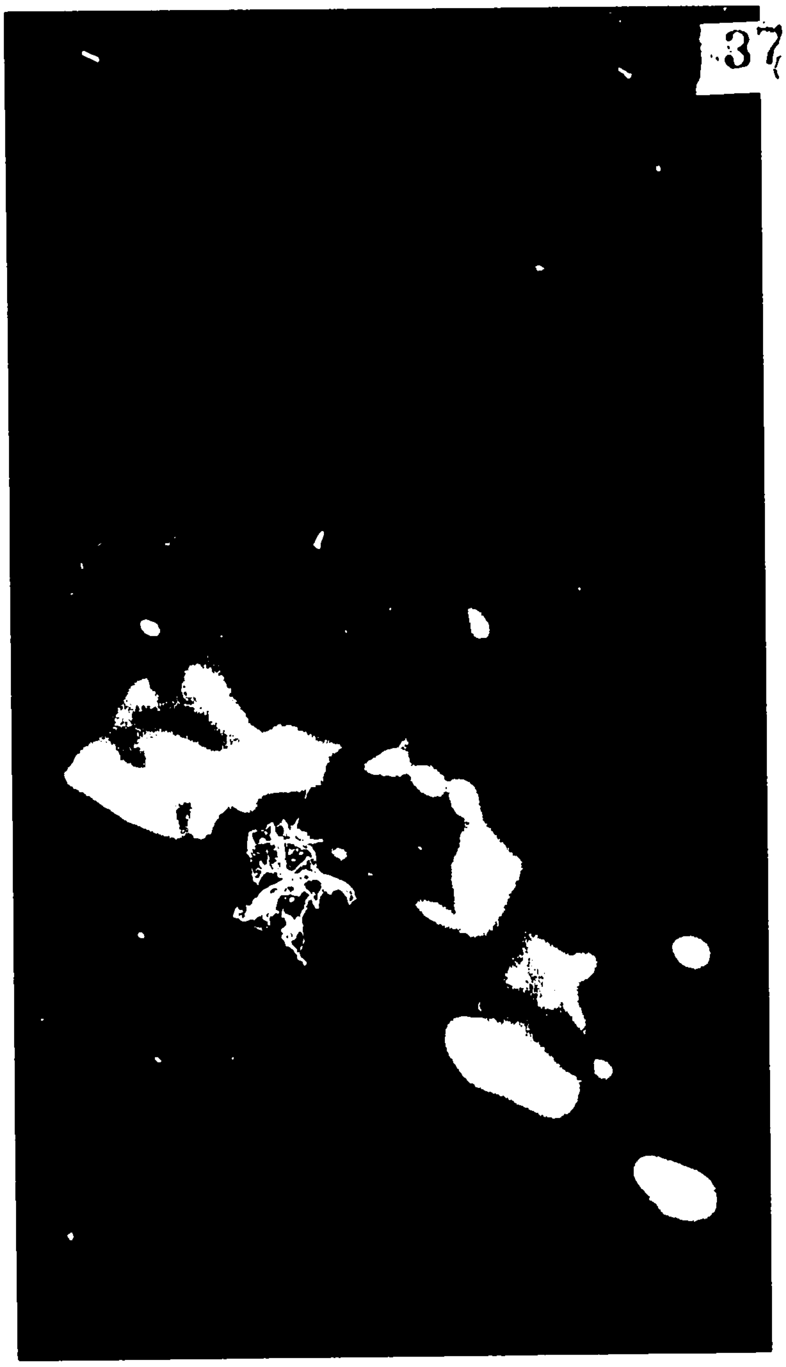
Intrepid's *powered descent on its last flight for science. The LM . . .*

. . . picks up speed

The LM Returns to the Moon

In previous lunar missions, the LM ascent stage has been jettisoned and fired into an orbit that would prevent its interfering with future missions. This time the *Intrepid* was to make a last contribution to science by being destroyed. With the crew reunited in the command and service module the LM was cast off and driven from orbit into the lunar surface. Traveling at approximately 5,000 mph, the 5,500 lb. (Earth weight) stage struck about 45 miles from the ALSEP seismometer. The force of the blow LM delivered was about 30,000,000 foot-pounds. On Earth, such an event would register a minor tremor for perhaps as long as 2 minutes on an Earth-type seismometer.

The results of the LM's impact on the Moon's surface astounded the geophysicists. The shock waves registered on the lunar seismometer for 55 minutes, building up to a peak at the 8-minute mark and then slowly declining. Dr. Maurice Ewing of Lamont Observatory exclaimed: "It was as though one had struck a bell in a church belfry a single blow and its reverberation had continued for 55 minutes." The phenomenon was completely outside any experience on Earth.



. . . as it arches down

. . . toward the lunar surface.

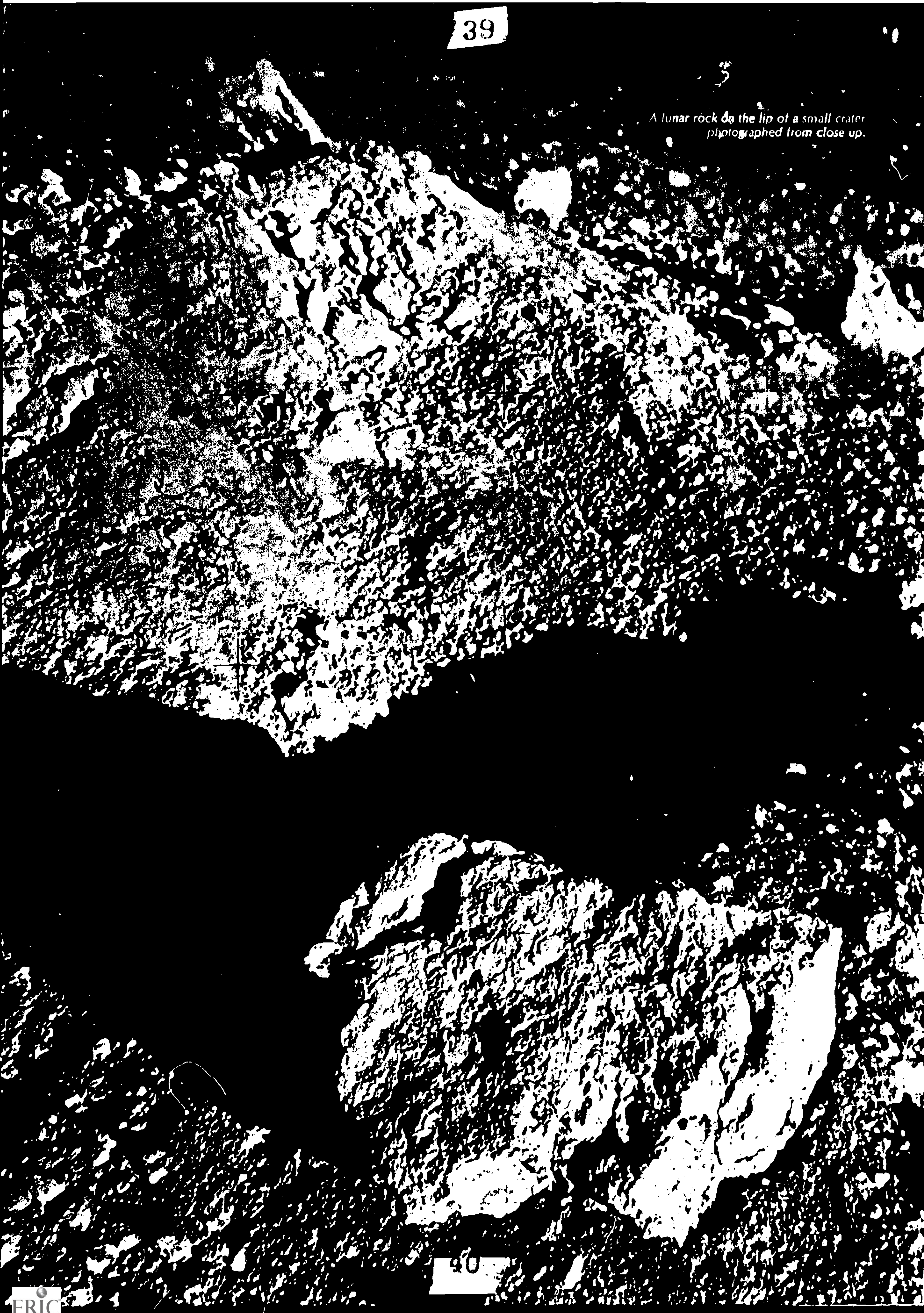
Early examination of the seismometer data reveals that the signal was received on the three pipe-like axes of the instrument that parallel the surface, but not on the vertical axis. If the vertical axis was functioning, this established that the shock wave traveled through the surface strata but lacked the strength to penetrate deep into the Moon and bounce back to the instrument. The signal was of low frequency and extremely low velocity: less than the velocity of sound in air.

The team of investigators offered several tentative hypotheses. The most plausible was that the shock waves traveled through a severely fragmented structure—a rubble—that was sandwiched between two reflective rock layers, the deepest of which was roughly 10 kilometers below the lunar surface. In this formation, they bounced back and forth as they would in an echo chamber.

Crashing the LM into the Moon provided the investigators with an invaluable yardstick for reading seismic data. The mass, velocity and point of impact of the LM were precisely known. It is thus possible to evaluate signals produced by other events by comparing them with the "gong" produced by the LM.

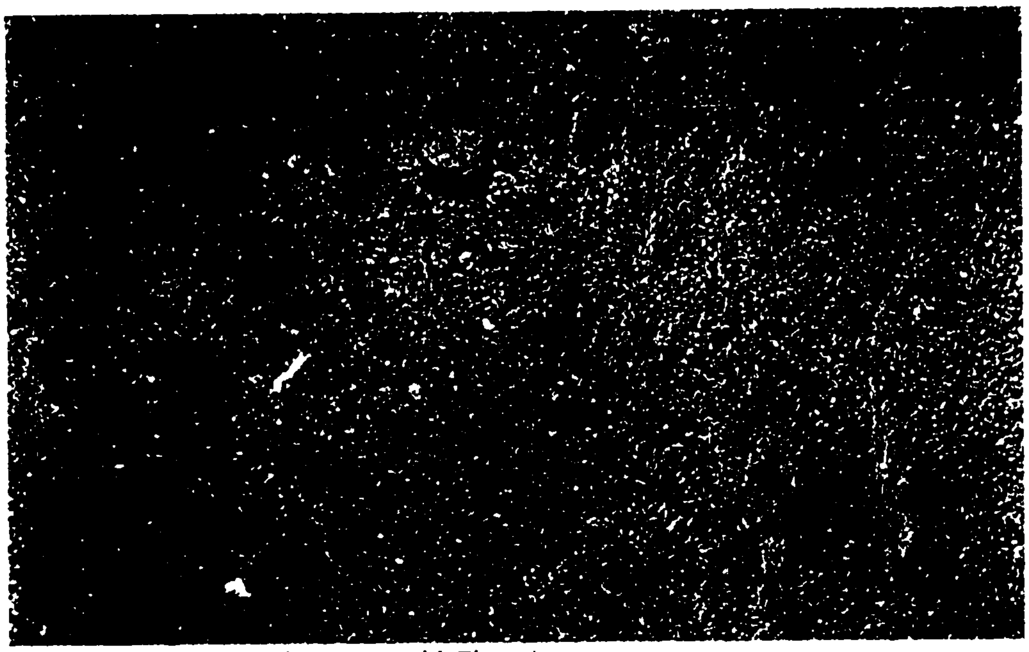
The more than 20 events recorded by the Apollo 11 seismometer since July 1969 can now be correctly interpreted, as well as readings from the instrument carried on the Apollo 12 mission.

Geophysicists are now awaiting Apollo 13 which will crash the larger Saturn V third stage into the Moon at a point from 200 to 400 miles from the seismometer. The more severe the impact, the more information it will yield.

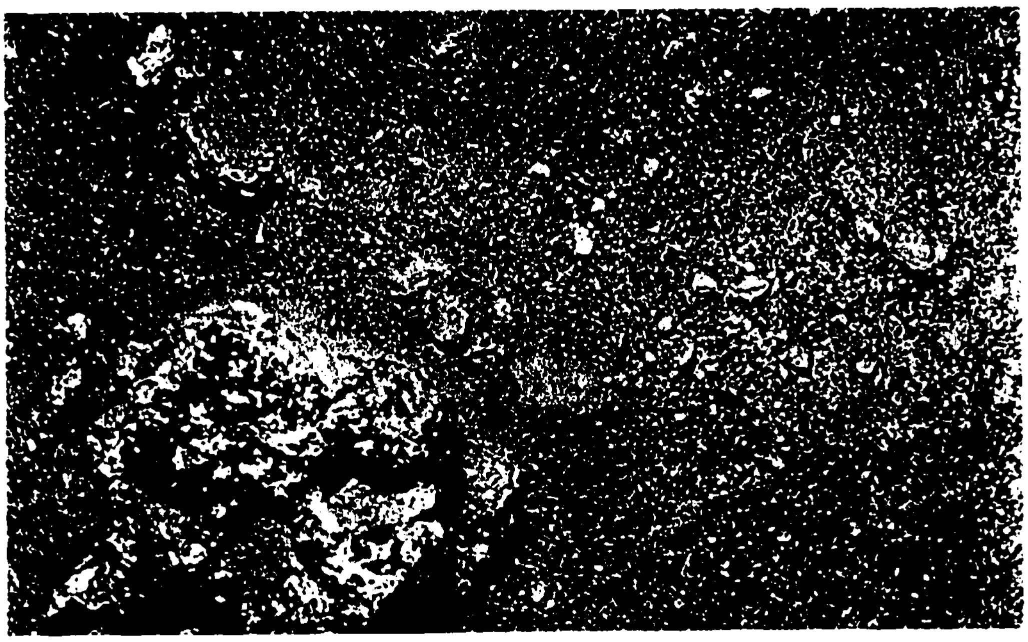


A lunar rock on the lip of a small crater photographed from close up.

A Veritable Feast



A small rock directly under the **Intrepid.** The exhaust swept the adjacent surfaces clear of dust but did not move the rock.



Another lunar rock with an iridescent coating.

Despite chuckles and whoops, and Conrad's humming from time to time, the sample collection that the crew of Apollo 12 brought back to Houston, and the commentary the crew supplied, verified the fact that they were indeed good "rock hounds." While the study of the samples and accompanying pictures is still in the preliminary stages, scientists are suggesting unique, and heretofore not possible, models which will lead to an understanding of the complex composition and history of the Moon.

The total of returned samples from Apollo 12 was approximately 75 pounds. The rocks vary from fine to coarse grained. One crystalline rock was very unusual because of large crystals more than 1 inch long. While scientists are not agreed on how such crystals may have been formed, to one school of thought, this indicates high pressures and temperatures and slow cooling. This group believes that such slow cooling occurs only at depths of more than a kilometer or in a massive lava flow that is cooling at its base. Another group of scientists ascribe to the "Hot-Moon" model. They suggest that these large crystals are evidence that the Moon was once made up of hot, igneous rocks formed from a silicate liquid. They are not certain what caused the melting—perhaps volcanism or perhaps impact of very large meteoroids; but what ever it was, they believe the Moon may have been hot for a long time—from 500 million to a billion years. Age determinations on samples from both Apollo missions suggest this.

In their lunar traverse, the astronauts covered three different types of surface. One was grooved and was first observed by Conrad in the area of the Lunar Module; a second, the firmer surface that Conrad and Bean reported south of *Bench* crater; and the third, the soft, powdery dust encountered around *Sharp* crater and inside several of the very small craters.

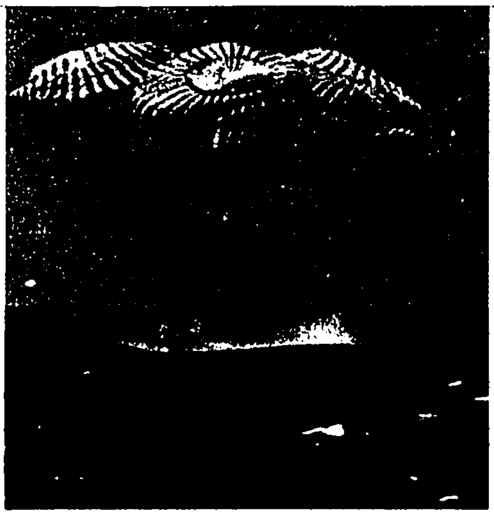
Geologists are of the opinion that the surface layer of pulverized material has been extensively churned by micrometeorite impacts which thoroughly mixed the materials. One experimenter described it as a "big blanket of beat up soil."

The lunar samples lack hydrated minerals which suggests that water did not exist when they were formed. There was no vesicular rock — rock with small spherical pockets in its matrix. Three of the four large rocks gathered by Bean near the end of the second walk were fine grained basalt with some crystal-lined cavities — presumably remnants of gas bubbles similar to those that appeared in the samples collected on Apollo 11. The fourth rock was much coarser grained and chemically different from the Apollo 11 samples. Its chemistry has indicated that potassium, uranium and thorium are in greater abundance while the titanium content was less than half that of rocks from the previous flight.

While the samples returned on Apollo 11 were 75 percent breccia, the breccia on Apollo 12 was less than 5 percent. Glass spherules were noted in both missions, but there were fewer glass beads in Apollo 12 material. The fine material returned was probably igneous lava that had cooled quickly with a rapid escape of gases.

One can say without question that new finds from Apollo 12 and the striking variation from Apollo 11 are dramatic proof that the Moon is an inhomogeneous body with a very complex history.

The Long Voyage Home



Yankee Clipper *splashes down in choppy seas.*

To accelerate Apollo 12 out of lunar orbit and into the narrow path that would bring the spacecraft back on the right course for safe re-entry and splashdown, the CSM engine was fired on the far side of the Moon. In this segment of lunar orbit there was no communication between Houston and the spacecraft.

As the spacecraft emerged from in back of the Moon and communications were reestablished, Houston asked: "How are things up near the Moon?"

Yankee Clipper replied: "Not too bad, but I think we're about ready to leave."

Houston said, "Glad to have you back."

The response: "We haven't met anybody up here."

A bit later, from the spacecraft, "Houston—Apollo 12's moving home."

For the next minutes, the crew turned cameras on the receding Moon "in true living color." For the benefit of Earth viewers, the lenses recorded the apparent topographical roughness of the terrain in the vicinity of terminator—the boundary between sunlight and darkness which, under a low Sun angle, looked "fairly smooth." The problem of determining color was unresolved, even at 500 nautical miles. *Yankee Clipper* reported: "The impression I get is that it is really useless . . . to have color out there because it is pure black and white. It just doesn't look right, it's so black and white."

For the next thousand miles, the crew turned the TV camera on various lunar features and discussed them with Houston. There was also some discussion, in retrospect, of the unusual characteristics of movement in the lunar environment. On the rock rolling experiment: "It was hard to get them going . . . everybody had the idea that in such light gravity things would roll down rather easily . . . that wasn't the case . . . you got it going and it just sort of went along in animated slow motion, but it kept going for a long, long time."

"I found I couldn't walk . . . wherever we went we loped and it just didn't seem natural not to. . . ."

Of the space suit, ". . . doesn't always want to bend like you want to . . . you can bend pretty well at your knee . . . at the ankles, but it doesn't want to bend up near the top of the thigh.

When the dialogue had finished, the Moon had shrunk to a 6-inch sphere out the window of *Yankee Clipper.*

Highlight of the return trip was the view of Earth's eclipse of the Sun.

Mission Profile

All Times EST

Time of Launch	**11:22 a.m. 14 November**
Elapsed Time Outward Leg	**83 hours 25 minutes**
Enter Lunar Orbit	**10:47:23 p.m. 17 November**
Intrepid Lands on Moon	**01:54:35 19 November**
Elapsed Time 1st Walk*	**3 hours 56 minutes**
Elapsed Time 2nd Walk*	**3 hours 49 minutes**
Total Time on Moon	**31 hours 31 minutes**
Intrepid Lifts Off Moon	**9:25:47 a.m. 20 November**
Leave Lunar Orbit	**3:49:16 p.m. 21 November**
Total Time in Lunar Orbit	**88 hours 56 minutes**
Elapsed Time Homeward Leg	**72 hours 14 minutes**
Splashdown	**3:58:24 p.m. 24 November**
Elapsed Time of Flight	**244 hours 36 minutes 25 seconds**
Total Distance Traveled	**953,000 Statute Miles**

*** Time measured from opening to closing of hatch.**

Two mid-course corrections put the spacecraft on target and Apollo 12 hit the water 3.5 nautical miles from the prime recovery ship, *Hornet.* The sea in the landing area was rougher than in any previous splashdowns, and the *Yankee Clipper* hit hard.

On recovery, the crew was immediately transferred to the mobile quarantine facility and remained there until they transferred to the Lunar Receiving Laboratory at Houston.

For this all-Navy crew, one phrase seemed especially apt: "Well done!"

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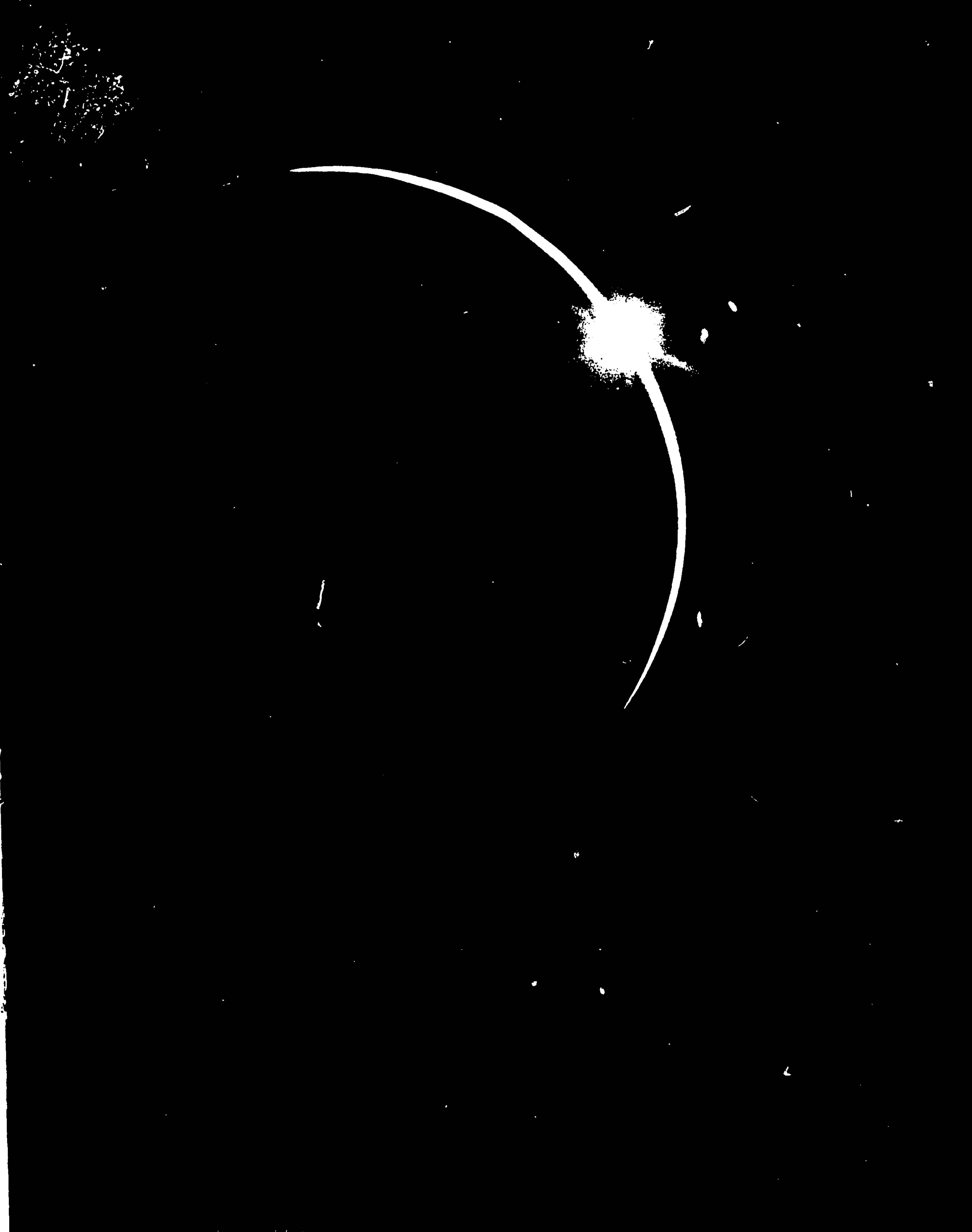

[illegible] Sun looks [illegible] but a [illegible] of the [illegible]. The astronaut reported [illegible] that they could not make out any surface features.