Geology on the Moon

Lee Silver has been teaching geology to Apollo crews for more than two years. For astronauts David Scott and James Irwin, the results were the impressive scientific achievements of the Apollo 15 lunar mission.

—got a boost on earth when Caltech's Leon Silver began sharing his professional skills and personal enthusiasm with the Apollo crews

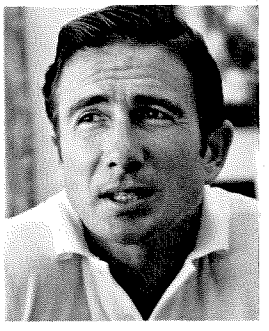
Lee Silver will probably never set foot on the moon. He'd like to, but he probably won't.

Yet he was there in a special way last August when Apollo 15 astronauts Dave Scott and Jim Irwin eased their lunar rover up along Hadley Delta and began investigating the moon's geology. He was there in spirit (only slightly less irascible than in the flesh) as head of geology field training for the Apollo program. With the beefed-up TV picture he was almost visible, a disreputable hat pulled low over his sun-sensitive nose and forehead, a bright red shirt on his back, his pockets stuffed with glasses, hand lens, and all the other bric-a-brac he carts along on geology field trips.

And Lee Silver was up to the old tricks that Scott and Irwin had come to know well—scolding, preaching, needling, wheedling, threatening, exhorting, praising, knocking—but above all moving the astronauts toward impossible standards, so that even if they fell a little short they would still surpass their own and everyone else's expectations. Everyone else, that is, except Lee Silver.

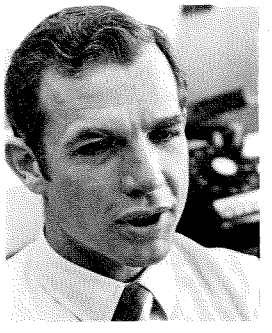
He's never satisfied. Ask anyone who has studied under him since he began teaching geology at Caltech in 1955. He piles on work. He makes outrageous demands. Morning field trips stretch into three-day survival tests. But through it all Leon T. Silver demands more of himself,

Interviewed at NASA's Manned Spacecraft Center in Houston, astronauts David Scott and James Irwin and Apollo 15 capsule communicator Joseph Allen comment on their geology training and trainer.



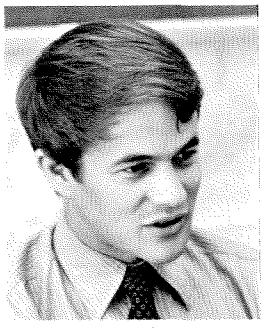
Irwin:

One thing Lee Silver always said was to step back and organize things in the proper perspective so you can relate them to the next scene that you see. I was thinking very much of him as I looked up at Mt. Hadley and saw all that organization in those layers up there. I thought: "Lee ought to be here to see this."



Scott:

Silver tough? Darn right! And I'm glad he's tough. He never let us get away with a thing.



Allen:

On a typical Lee Silver trip, he'd make arrangements wherever we were staying to open up the kitchen earlier because he wanted to get an early start. We'd be eating breakfast at five o'clock in the morning. Dave and Jim worked very hard and very, very long with Lee; and Lee, of course, was right in there working for hours and hours trying to get them up to the level of efficiency he wanted.

A simulated lunar traverse is almost as complex as the real thing—and closely monitored as well. Astronauts Irwin and Scott perform their assigned tasks at Rio Grande Gorge, followed and observed by Lee Silver and Gerald Griffin, an Apollo 15 flight director.

and gives more of himself, than anyone else. He's usually liked. Always respected. His colleague Robert Sharp, who was chairman of Caltech's geology division from 1952 to 1968, thinks he's also the best all-round geologist in the country.

When it was decided three years ago to provide formal geology training for the astronauts, Lee Silver was the man they came to. Characteristically, he accepted, beginning his work with the Apollo 13 crew. He's walked some of the roughest terrain in the world with the astronauts, taught them, and even cooked for them: on the high desert plateaus in the San Juan Mountains north of Durango, Colorado; in the Mojave; along the Rio Grande Gorge out of Taos, New Mexico; at Kilauea Crater on the island of Hawaii; in southern California's San Gabriel range.

At the same time, he has been getting more and more deeply involved in other aspects of the science portion of the missions. Apollo 15 brought him a sort of scientist's grand slam: In addition to training the crew, he took part in planning the traverses, manning the science back-room during the mission, and examining the lunar samples. He is now analyzing part of that collection. His Caltech teaching and research load is no lighter either.

Silver probably didn't fully comprehend the eventual

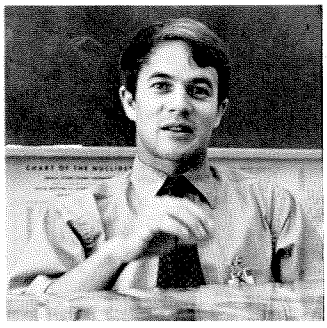
depth of his involvement when he began working with the prime Apollo 13 astronauts, Jim Lovell and Fred Haise, and the backup crewmen, John Young and Charles Duke. The idea started with Lovell, who had discussed his interest in geology training with fellow astronaut Harrison Schmitt, one of Silver's former students at Caltech (BS '57). Schmitt and Gene Shoemaker, now chairman of the division of geological and planetary sciences, suggested Silver as teacher and offered to approach him on the subject. As soon as Silver was signed on, Lovell made the decision that delivered the astronauts to the professor's tender mercies. There was no formal NASA approval at the time. As commander, Lovell had the clout.

Late September 1969 found the astronauts, Silver, postdoctoral fellow Tom Anderson, and a couple of others high in a remote mountain range of the Colorado desert. Nobody knew what to expect, creating a human vacuum into which Silver stepped to ramrod a full week of grueling instruction. ("I worked their tails off.") It was also a time of mutual testing, after which the astronauts endorsed the results and asked Silver to continue.

With Apollo 13 set for launch in April 1970, there was time for only a few field trips. After the last session in March, Young and Duke—already tabbed as the prime Apollo 16 crew—got Silver's promise to train with them. Meanwhile, Scott and Irwin were hatching a similar idea with the help of Harrison Schmitt. A quick trip to Cape Kennedy, dinner and a lengthy talk session, a trial period in the desert, and Silver found himself pledged as trainer for the Apollo 15 flight. (Apollo 13 never reached the lunar surface, but the masterful handling of that explosion-crippled ship by Lovell, Haise, and Swigert remains one of the most dramatic achievements in manned space flight.)

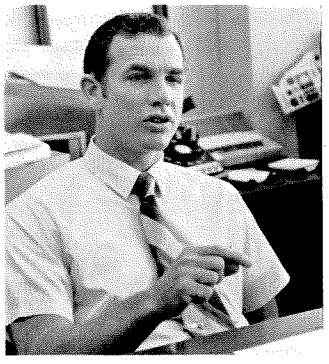
During the 15 months Silver spent on Apollo 15, the operation evolved into a combined U.S. Geological Survey and NASA institution, formalized by an official training document drafted by Dr. Tony England, mission scientist for Apollo 13 (and now for Apollo 16). Gone were the small groups of six or seven men jouncing around the outlands in Caltech carryalls. The complement had grown now to 40 people and included both mission scientists and flight directors who got their first real taste of what it means to get lost or to try to chip a sample off a reluctant rock or to overlook a potentially important find.

Basic geology was still central, but the exercises became more and more like dress rehearsals for the real thing. Traverses—or the routes over which the crews would pass—were being carefully thought out in advance. The crews worked from assigned maps like those carried on the actual mission, and there were assigned stations along the traverse, each station with its required tasks, each to be



Allen:

Right now we're at the point where the Apollo 15 material is going out to hundreds of laboratories all over the country. We took a strictly preliminary look at the samples here in our own labs—Dr. Silver took part in that, too—before they were divided up to be studied. A lot go out to Caltech, by the way, and Dr. Silver has his share of those.

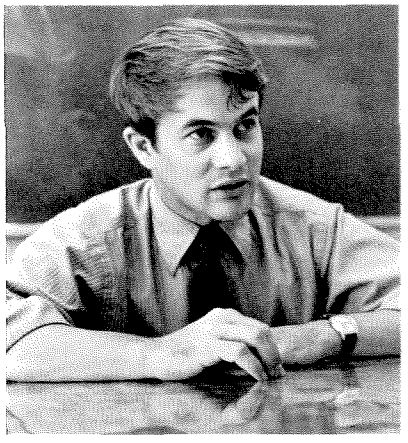


Scott:

Our crew had about 1,800 hours of formal training, 600 of which were devoted to science. We felt that the Apollo system was mature and reliable and that we no longer had to devote the time to engineering that we had on past flights. Now we know the system and we have confidence, not only in the manufacture and check-out, but also in the people on the ground during the flight. If we have a problem, we know there are experts down here who can come up with the answers.

So once you get this confidence in the system, you ask: "Where should I spend my time?" It was obvious to me that the time should be spent in learning the science. We had additional opportunity, too, because we were the backup crew on Apollo 12 and spent that time learning how to fly the machine. When our turn came on Apollo 15, we already knew how to work together. This gave us a great opportunity to devote our time to the science part.

That's the whole purpose behind Apollo. The original concept was to have test flights to make sure it worked, a few more to make sure we could land on the moon and return, and then, by golly, to get into the real meat of the subject. That was the whole purpose. We were lucky enough to be in the position to participate in the meat part.



Allen:

We started out on field trips just exactly like any student from Caltech. They weren't like a lunar traverse at all—more like a field trip you'd take in a lab course. The object was to learn terrestrial and observational geology, because after all, that's what's being applied on the moon. Then little by little, as we got closer to the mission, we got pretty proficient at doing the terrestrial geology. We started playing the game by lunar rules, not only to learn geology, but also to practice the situation we were going to find ourselves in when it came to the three days of the mission traverse. Dave and Jim would then use all the lunar tools and lunar procedures—cameras and everything else. And we'd have a backroom set up to try to direct and interpret and guide what was going on out there in the field—maybe a quarter of a mile or a mile away. One of the rules toward the end was that we in the backroom wouldn't be able to see them.

Irwin:

I guess I was most impressed with Lee's enthusiasm, his zest, his ability to keep going hour after hour without wearing out. He kept us very busy. We'd debrief late into the night, and as a practice, we'd always retraverse the path to review the things we should have seen. Sometimes we'd end up doing that after dark by flashlight.

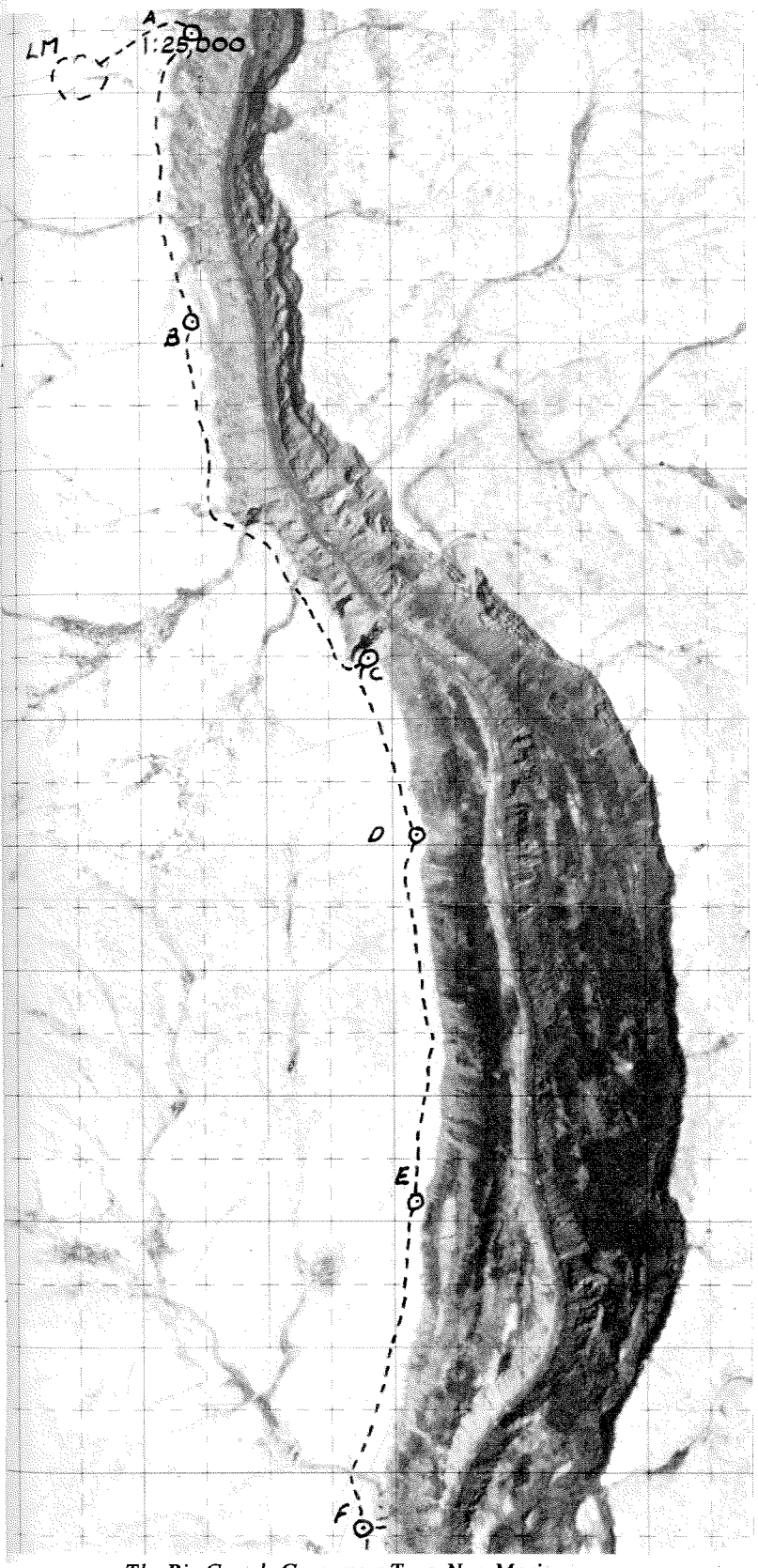
reached by a time specified in advance. Two science backrooms (one apiece for the prime and backup crews) were added to provide radio communications to and from the astronauts during the exercise. This wrinkle not only provided a higher degree of realism, but it also enabled crews and flight directors to apply considerable polish toward a more smoothly functioning communications system at mission time.

As for Silver, he was still out there observing the crews' performance as they walked the traverses or toured them in "Grover," the earthbound cousin to the lunar rover they would take along to the moon. The pace was hectic, the exercises no less challenging, and Silver's basic article of faith endured—demonstrating what geology can contribute as an integral part of the Apollo program and reinforcing his own appreciation of man as "the most incredible sensing and computing device we have at the moment."

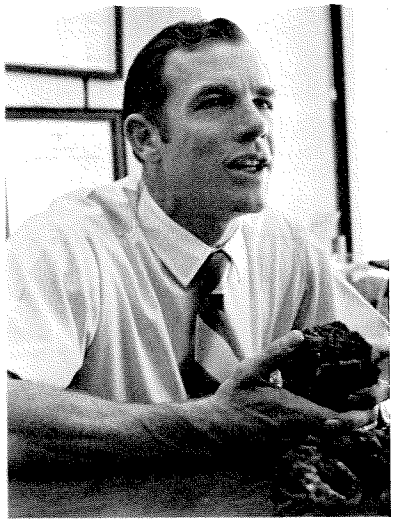
For someone as intensely committed to the program and these objectives as Silver, there are disadvantages in expanding the geology field training program. Geology has to compete with the other urgent lessons—learning how to use cameras and other special tools, refining communication techniques. And there's the added problem of maintaining continuity and format when the basic geological portions of the exercise are put together by experts who come aboard for a single field trip. But to Silver the major loss is the personal element, the opportunity to present geology as the singular personal science that it is. While Silver may regret this loss, he doesn't dwell on it—and he likes having someone else do the cooking now almost as much as the crews enjoy being off KP.

Silver made almost every field trip during the Apollo 15 preparation. As on earlier missions, he and other geologists—Caltech's Bob Sharp was one—carefully selected terrain that illustrated geological phenomena useful to the missions. As it turns out, this is no easy task. A forced analogy can create false impressions, and Silver and the rest of the highly qualified professional staff from the USGS and NASA's Manned Spacecraft Center were forced deep into their creative bags to come up with suitable field trip sites. To complicate matters further there was the challenge to fan interest and fuel motivation. To Silver, an interesting and attractive environment is the difference between a productive or unproductive learning experience. He's adamant on the notion that you don't have to do geology in ugly places, eat poorly cooked food, and go to bed dirty. All of this is calculated to promote student enthusiasm and momentum.

Of course, good teachers have always known this, and Silver carries a reputation as a good teacher. Astronauts, however, do present a special case. For one thing, they are disciplined achievers who labor mightily as long as they feel a sense of accomplishment. At the same time, the demands on their time don't permit any of it to be wasted.

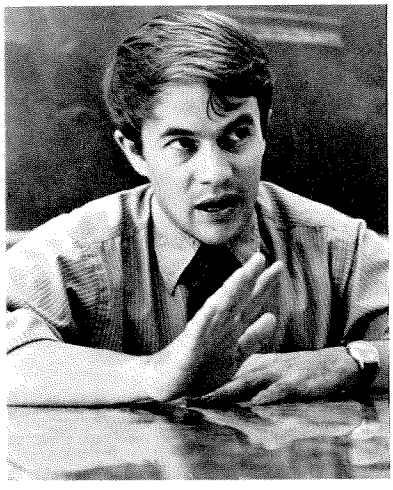


The Rio Grande Gorge near Taos, New Mexico, has some topographical similarities to Hadley Rille on the moon. Covering the traverse indicated along the west side of the gorge was part of the training for the Apollo 15 lunar mission crews.



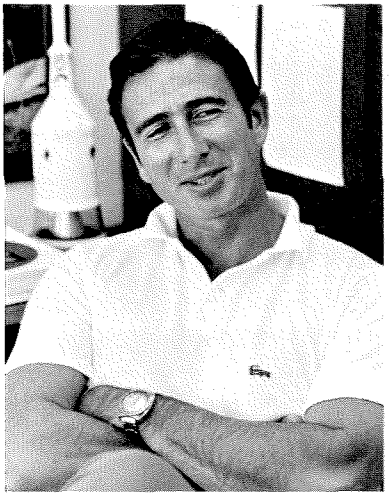
Scott:

We had four hours to go from A to B, analyze the geological setting, and bring back the samples and the photographs. We had station tasks just like on the moon. Our capsule communicator, scientist-astronaut Joe Allen, was with us. We had our radios, and after a while, we worked with the people in the backroom at CapCom. We did it just like we were on the moon. We'd run this excursion for four hours, come back and brief Professor Silver on what we saw and why we saw it. He'd listen, not saying anything until we were all through. Then he'd take us back and show us what the real story was.



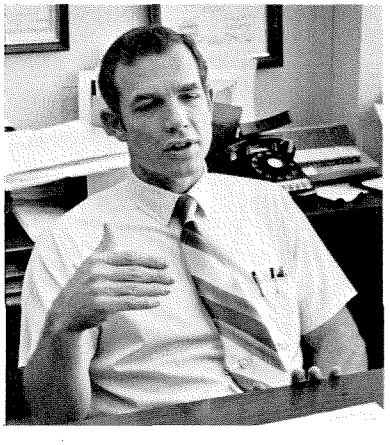
Allen:

Dr. Silver is one of the best teachers I've ever run across. He gets his subject across with enthusiasm and a lot of correct information. But the enthusiasm is always there, and that's got to be the key to any success a teacher has. Without it he can't teach anything. In this case Lee was dealing with people who are somewhat older than the average Caltech student, but that didn't seem to make any difference. The enthusiasm became mutual.



Irwin:

It's a matter of practice, so that doing the right thing is automatic. We'd practiced for so many hours in the field that we didn't know any other way to do it. And, of course, we'd had a lot of practice taking pictures also. When we got up there on the moon doing geology, we felt right at home using all the equipment. It was a little easier at 1/6th G, but we'd gone through it so many times that our actions were almost automatic. It was just like being out on one of the field trips to the mountains on the earth. I felt right at home. I had to remind myself frequently that I was really on the moon.



Scott:

We all agreed to start running our field trips exactly like we would conduct an excursion on the moon. Take the equipment with us that we use on the moon—except for the pressure suit, which was impractical. But take the tongs and the hammers and the bags and the cameras, and do an actual simulated lunar traverse. We were briefed on it beforehand, and we had photographs. The USGS at Flagstaff was really great in supplying lunar scale photos for us. We'd get to a locale in the evening and have a briefing to talk about the photographs and the excursion the next day. When we went on a geology field trip, we performed the lunar field geology experiment only. This was pure geology—nothing else.

Then too, they are mature, gifted, and sophisticated and must be approached on an individual level. In a very important way, effective training becomes a game of finding keys to unlock interests, curiosity, and responses. Silver clearly prefers to describe it as "creative instruction." He also clearly enjoys the test of wits.

In the Apollo geology field training program, terrestrial instruction is designed with much more in mind than introducing geologic features or learning names and geologic periods. Each exercise underscores geological principles: reliable observation, effective documentation, and scrupulous distinction between observation and interpretation. Silver and the astronauts rehearsed until running down the geology mental checklist became almost as instinctive to Scott and Irwin as running down the checklist before taking off in an aircraft: A rock. OK. Color? Shape? Pitted or smooth? Record how it looks before it's picked up. Detail, facts, data—Bob Sharp calls it "calisthenics"; not very exciting, but essential. As proxies for all the geologists in the world, however, the Apollo crews took their responsibility to heart. The astronauts gradually learned how to see the earth through Lee Silver's eyes. Last August they returned the compliment by showing us the moon through their own.

In the early training days, there was no set format. Teacher and students learned from each other, the students assimilating geology, the teacher how to crowd the most useful information into an already full schedule, to recognize operational constraints, to adjust to them. Together they honed the training procedures to a fine edge on the whetstone of basic principles. Then there was an element of spontaneity, with formal structure all but invisible. But no longer. Today there is extended advance study of specific mission traverses. Training exercises are run by the stopwatch. And Silver is only one of several outstanding USGS specialists active in this operation.

To simulate conditions that the Apollo 15 crew would confront at Hadley Rille, exercises were run at the rugged Rio Grande Gorge. Camera equipment was identical to that selected for the flight. Maps were simulated in the same format to be used on the lunar surface. The USGS staff prepared stations and technical problems that were facsimiles of those anticipated along the actual traverse. Exercises themselves took place at the precise time of day that duplicated light angles on the moon. Scott and Irwin snaked over the traverse on foot or in Grover, and flight directors monitored and directed from backrooms like those at Houston's NASA Manned Spacecraft Center. Silver says the operation has come a long way in sophistication, and he gives most of the credit to Dr. Gordon Swann and the U.S. Geological Survey staff in Flagstaff, Arizona. Swann is principal investigator for the Lunar Surface Geology Experiment; Silver is one of his co-investigators.

The work that Swann, Silver, and their colleagues perform seems complex enough, but Silver views it as

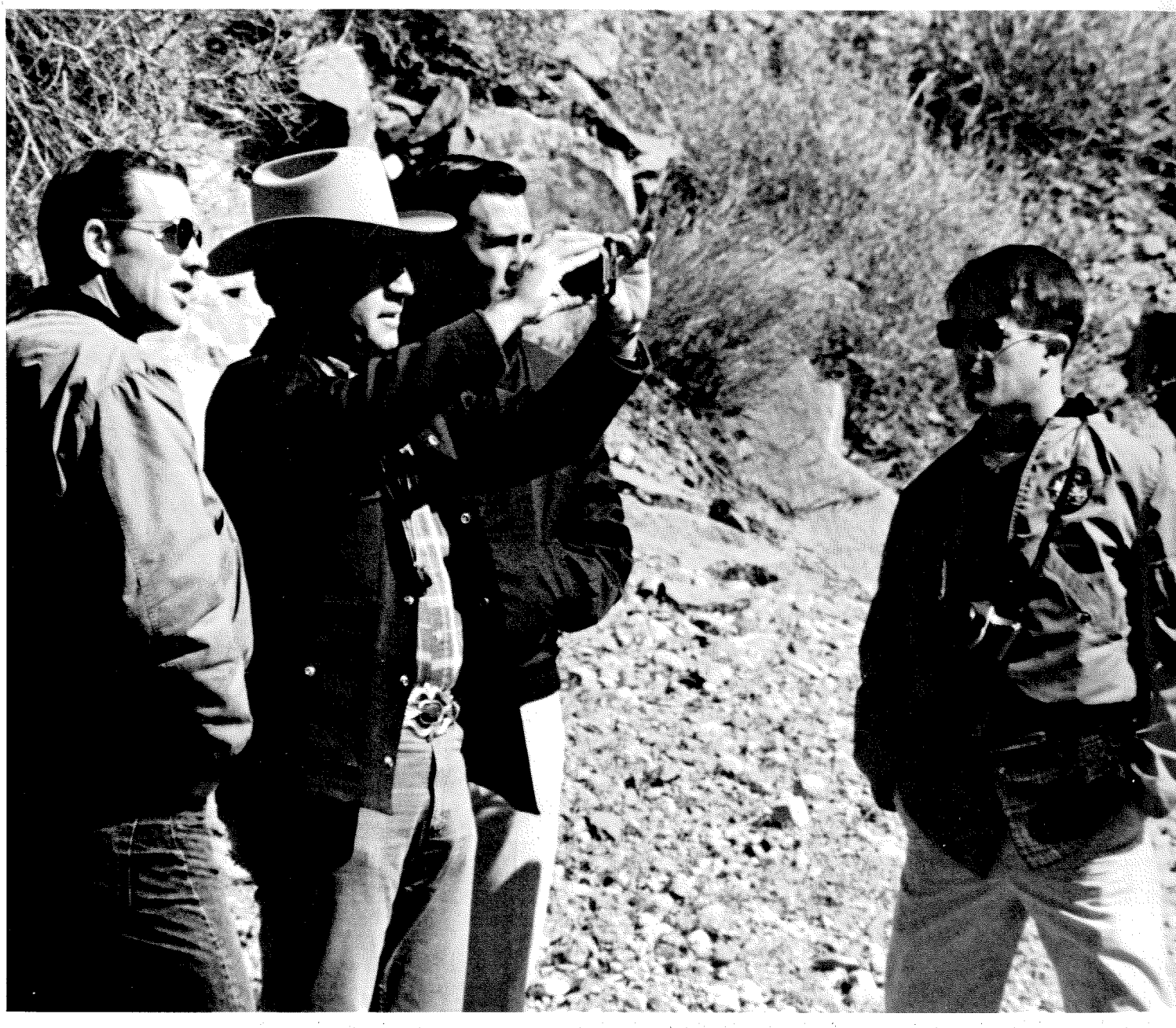
Parked on the rim of a 30-foot crater at Cinder Lake crater field in Arizona, astronauts Irwin and Scott survey the terrain. Their transport is the terrestrial version of the lunar rover—the "Grover."

just one part—albeit important—in an enormously involved scientific and engineering effort. He is also quick to point out that specific lunar missions, while both dramatic and important in their own right, are just part of a total Apollo experiment that will be many years in the unrolling. He would like to see it through, although its demands on him—added to his campus duties—have become formidable.

One of the sources of his perseverance is his attachment to the astronauts. He compares them with the best of Caltech graduate students and finds they have extraordinary powers of observation and response, of discipline and determination. "First-rate" is the label he attaches to their talents as engineers and fliers. One of the things that really impresses Silver is the ability of the crewmen to keep their spirits and interest from drooping. Scott and Irwin, for example, are now backup for Apollo 17; and Fred Haise, lunar module pilot for Apollo 13, now commands the backup crew for the upcoming 16 mission. Yet Silver has detected no loss of momentum from this prolonged pressure or from the towering demands of total mission preparation.

Beyond professional admiration, Silver carries an unmistakable personal regard for the NASA fliers. He

One indispensable piece of equipment for the geologist is a Brunton Compass—a leveling device to measure relative elevations. Looking across at a lava flow, Lee Silver utilizes the instrument for the benefit of David Scott, Raymond G. Zedekar (chief of the lunar surface procedures section for NASA), and Joseph Allen.



likes their spirit, their honesty, their lack of pretensions. It's the kind of friendship born of shared aspirations, mutual willingness to find the best way, and mutual satisfaction at achieving important goals. Bob Sharp says this is common among geologists who work on long-term projects that require a lot of time in the field. The astronauts fitted right into the pattern.

Silver and Sharp think the astronauts learned a lot of geology on their trips, and any casual TV viewer of the Apollo 15 proceedings will recall that their geology dazzled Walter Cronkite. Silver attributes some of this expertise to the fact that even prior to their assignments to Apollo missions the astronauts had had exposure to geology lectures, field trips all over the world, and an opportunity as fliers to develop their aesthetic appreciation of the earth's features. And as subsequent missions contributed to increased systems reliability in the spacecraft, there was time available for greater emphasis on geology. But the real key probably lies in the makeup of the students themselves. Achievers all, they thrive on understanding and personal mastery of new horizons that advance their contributions to the program.

Silver had a seat up front in the science operations room at Houston during the 12 days of Apollo 15. Typically, he was working—as part of the Science Operations Team. When Scott, Irwin, and Worden returned with 180 pounds of samples and the first interpretations began to come in, Silver was inundated by the press along with everyone else connected with the mission. He still grumbles that the printed stories sacrificed scientific content for dramatic impact.

On October 5 he was invited down to Houston again, and NASA Administrator James C. Fletcher gave him the NASA Exceptional Scientific Achievement Award:

> *For his significant scientific achievements in the development of highly precise isotopic compositions of uranium and lead in minerals and the applications of the age determination procedures in the analyses of lunar material. While diligently conducting these laboratory investigations of lunar material, he provided a major contribution by training the astronauts in geological sciences which, through his enthusiasm, leadership and guidance, has led to the successful exploration of the moon.*

The lunar traverse planning team of which he was a member received a NASA Group Achievement Award for its work.

For Dave Scott, Jim Irwin, Al Worden, Joe Allen, and many other friends of Lee Silver who were there looking on—and for Silver himself—it was a very special day.

—Harry Bain,
Jacquelyn Hershey

Irwin:

Well, we were exposed to a lot of geology. Lee really gave us both barrels every time we went out. He presented a challenge to us, and it all paid off when we got up there.

Scott:

We have so much to learn, so many different disciplines. We have to learn to fly a wingless vehicle and to fly with a vehicle that weighs six million pounds. We must learn how the pressure suit works, how the computer works, why it doesn't work if it doesn't. The number of different disciplines—to quote a phrase from Dr. Silver—is mind-boggling.

We had classroom study and field trips beginning early in 1964. These would be "show and tell" kinds of trips where prominent geologists demonstrated various samples and geological settings at different local sites. When we went out with Dr. Silver, for about the last year, each trip was a kind of "final examination." We would go out and demonstrate to our good professor what we knew—force ourselves to expound on what we knew. His enthusiasm was a significant factor in our ability to communicate. It rubbed off on us. You name the discipline, and I can force myself to learn it, but there's a difference between that and wanting to learn because you enjoy it. And that's what I got from Dr. Silver—the motivation. He made it fun. I can't go anywhere now without picking up rocks.