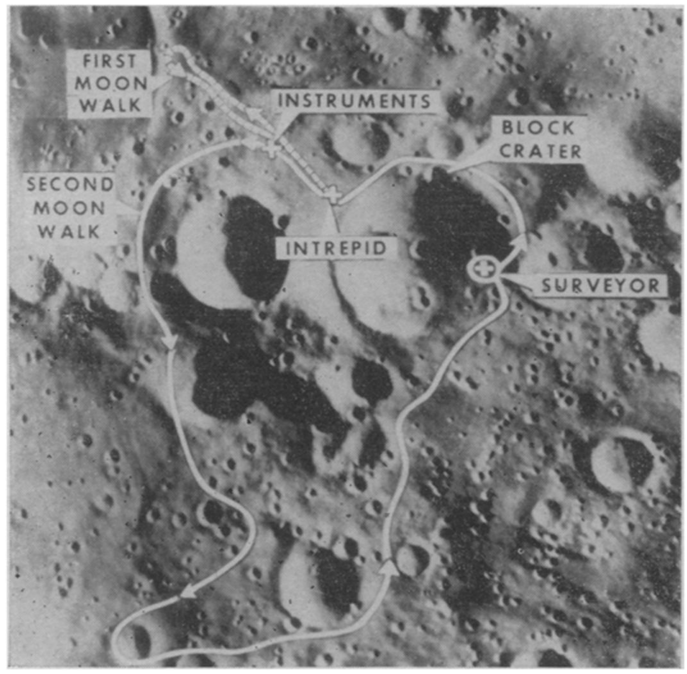


NASA/Wide World

Fruits from Apollo 12 moonwalks are ripening already.

Apollo 12's moon: surprises already

It may be an engineering program, but Apollo 12 is already giving scientists more than they expected

Despite the pioneering efforts of Galileo, who transformed the moon from a ball of light to a ball of rock, and centuries of research in his wake, great gaps remain in man's knowledge of his world's natural satellite. Apollo 11 began the quest for first-hand answers, but it took Apollo 12 to demonstrate, even before its astronauts arrived safely back on earth this week, that great surprises are still in store.

Charles Conrad and Alan Bean, who walked the moon (SN: 11/22, p. 470), and command module pilot Richard Gordon, splashed safely down in the choppy South Pacific off Samoa Monday. With them came some 90 pounds of lunar rock and dust samples, plus hundreds of photos to aid selenologists and astronaut pilot-trainees. In exchange, they had left on the moon the ALSEP group of scientific experiments powered by radioisotopes and controlled remotely from earth.

Though they should continue to operate for at least a year, two of ALSEP's instruments have already caused scientific double takes.

The first surprise was reported by a passive seismometer, a highly refined ear tuned to shocks and shakings in the lunar structure; the strength and decay rates of the tremors can be analyzed to reveal the structures through which the tremors passed to reach the seismometer. To provide a big enough shock to cause tremors well below the lunar surface, the Apollo 12 astronauts sent their empty lunar module, Intrepid, crashing back into the moon with a momentum of some 30 million foot-pounds per second.

Scientists monitoring the seismometer on earth, led by Dr. Gary Latham of Lamont Geological Observatory, expected a brief shock that would wiggle the pens on their chart recorder and die out in a few minutes. To their astonishment, the vibrations lasted nearly an hour.

The indications from the seismometer were almost invisible at first, says Dr. Latham, and took seven or eight minutes to reach a maximum. But the surprise lay in their longevity. It was at least 5 minutes before any weakening was visible at all, and 20 minutes before the waves were down to half strength, says Capt. Lee R. Scherer, director of the Apollo Lunar Exploration Office, who watched the tenacious shock waves unroll with more than two dozen other scientists in the science support room just off the mission control center in Houston. From the first tremor, they lasted some 55 minutes.

The theorists were caught unprepared, which, as is often the case, produced even more hypotheses to fill the breach than would have appeared from data that supported somebody's pet moon model.

Looking at the early data, Dr. Frank Press of Massachusetts Institute of Technology suggested that the LM impact might have touched off "a cascade of avalanches and collapses over a very large area." Another conjecture was that the crash might have thrown debris so high that, falling slowly in the moon's low gravity, it took almost an hour to come back down.

It was even proposed that the LM itself might be to blame. Since the empty spacecraft was not driven straight down to the moon like a hammer blow, but rather sent on a shallow descent similar to a landing, it hit the surface at a flat angle: less than four degrees above the horizontal. This, the idea goes, could have caused it to skip across the Ocean of Storms like a flat stone on a stream, dropping off parts as it went. Such a series of blows, however, would be unlikely to produce the sustained, large tremor recorded by the seismometer; the same argument applies to the falling-moon-debris theory.

During the first day or two after the event, many researchers were reluctant even to try to invent a lunar model that would fit the strange phenomenon. Some such models would have made for a rather bizarre moon, "such as a hollow titanium ball," smiles Capt. Scherer, "which is highly unlikely."

There is always a leading theory, however, and one does seem to have emerged. The likeliest mechanism in Dr. Latham's book is a sandwich-like structure that trapped the energy of the blow between two hard layers so that it kept resonating back and forth, up and down, without being dissipated into the depths of the moon.

The top layer is the bedrock comprising the floor of the Ocean of Storms, believed to extend down for about a kilometer, while the bottom is a similar, but much more ancient, bed of mare-like material.

Like most sandwiches, however, the essence is in the middle. Filling the space, Dr. Latham theorizes, is a layer of rubble, ranging from multi-ton boulders down to gravel and varying from 100 to 500 kilometers thick. The rubble was probably thrown out by the impact of the huge meteor that formed

Mare Imbrium, 1,000 kilometers across and visible from the earth even to the naked eye, just east of the Ocean of Storms.

On earth, such rubble would be a terrible conductor of tremors; on the geologist's "Q" scale, a measure of how long vibrations in the earth take to die down, it would rate about 10. By contrast, the moon rubble scores at least 2,000. The difference is that the earth rubble would be filled with gases and liquids that would let the vibrations travel at high speeds, enabling them to penetrate far down into the planet. On the moon, these have long since boiled away, leaving a very low-velocity material that can slow down seismic waves enough to trap them between the hard layers above and below.

The Apollo 11 seismometer, left on the moon in July, picked up about 100 similar, though smaller, seismic events which resonated for up to 20 minutes. "No one was prepared to accept the fact that they might be due to impacts," Dr. Latham says, "but now we think differently." Re-studying the Apollo 11 data—its seismometer finally froze to death in the lunar night—may thus provide the first accurate measurements of the rate at which meteorites bombard the moon.

Apollo 13 should add a great deal to Apollo 12's exciting discovery. Its site is a bed of ejected material from Imbrium not covered by any hard layer. Samples of this rock should tell scientists how long ago Mare Imbrium—and thus the middle of the Ocean of Storms sandwich—was formed. In addition, the third-stage booster that sends Apollo 13 off toward the moon will later be sent to crash into the lunar surface, within 220 miles of the Apollo 12 seismometer. It will hit before the astronauts land, so safety should not be a concern, and it should provide a blow with almost six times the momentum of the Intrepid.

It is also likely, Dr. Latham believes, that the Apollo 13 astronauts will be able to find rocks on the surface that were part of the same layer that forms the bottom of the sandwich. Such rocks, even older than Imbrium, would be the oldest ever found on the moon, and could well confound more theorists by being even older than present estimates of the age of the solar system.

The seismometer was not the only ALSEP instrument to start out with a surprise. Also monitoring the state of the moon is an ultrasensitive magnetometer.

Past measurements of the lunar field have been limited at best, and all seemed to point to a field approaching zero. The first close-up data came from Russia's Lunik 2, the first man-made object to touch the lunar surface, which crashed there in 1959. Before the collision, the spacecraft radioed back that it could detect no field at all, meaning that if there was one, it was weaker than the instrument's sensitivity of 50 gammas. Earth's magnetic field is some 35,000 gammas.

Next came Lunik 10, also an unmanned Soviet craft, which orbited the moon in 1966 and reported a field of from 23 to 40 gammas. The following year, however, the U.S. launched Explorer 35, fifth satellite in the Interplanetary Monitoring Platform series, which determined from its moon-circling orbit that the field was less than 16 gammas. The implication definitely seemed to be downward, leading to the conclusion that the chances of the moon's having a molten core (now or at some time in history) were slim. A molten moon, if still fluid, would produce a magnetic field by electric currents from its turbulence; if long since cooled, it might have aligned the then-plastic lunar rock along the field lines into a huge dipole magnet.

Now the ALSEP magnetometer has found what may be evidence of a core after all. Within days of being turned on by the astronauts, it has detected an ambient magnetic field of some 30 gammas, twice that of previous estimates.

In coming days and weeks, the data will be compared with other information derived from studies of the orbits of the Lunar Orbiter spacecraft to help pin down the number. In addition, comparisons will be made with data from Explorer 35; the magnetic field is sure to be deflecting electrons and protons coming from the sun, with the result that fewer particles should be reaching the surface than hit the spacecraft.

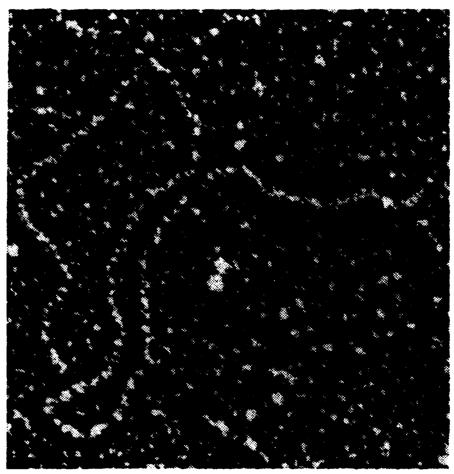
Meanwhile, the astronauts and the lunar samples are again in quarantine, while an enlarged group of outside investigators waits to get its hands on the priceless pieces of the moon. □

A SINGLE GENE

Molecular tour de force

According to a now classic hypothesis in genetics, there are two classes of genes. The first consists of structural genes that, through RNA, determine the sequence of the amino acids and thus the structure of protein. The second class of genes, called operators, control the first, turning them on and off to regulate gene expression. Working as a unit, a package of structural and operator genes is called an operon.

While there is already considerable circumstantial evidence to support this view, its final confirmation and new insights into the detailed mechanisms by which gene classes interact may now be possible because scientists have isolated a single gene from the common intestinal bacterium called *Escherichia coli,* or *E. coli.* With the assistance of viruses, a team led by Dr. Jonathan Beckwith at the Harvard Medical School has achieved a skillful molecular tour de force that at once gives scientists pure genes for study and a method of obtaining more.



Harvard Medical School

A single lac gene, 1.4 microns long.

The gene they isolated, the lac operon, regulates the production of an enzyme called beta-galacto-sidase, which degrades or breaks down lactose. "What we have," says Dr. Beckwith, "is a piece of DNA that contains the gene that controls the structure of lactose, and the regulator or controlling sites of that gene."

With Dr. James Shapiro and Lawrence Eron, Dr. Beckwith began by selecting two bacteriophages (viruses that infect bacteria) that get into an *E. coli* cell and incorporate into their own genetic material the bacterial lactose gene. "The two phages we isolated, lambda-plac5 and phi-80placl, are very similar in all regards, including their ability to pick up lactose genes," Dr. Beckwith says, "but their strandedness is different." That is, the sequence of bases that make up the lactose gene face in opposite directions.

In the laboratory, the Harvard team isolated the DNA from each phage, treated it with chemicals to force the helix to uncoil and then put together a single DNA strand from each. Because only the portions of those single strands that held the lactose gene matched, they joined to form a whole, coiled lactose gene; the remaining DNA remained separate. When that extraneous DNA was