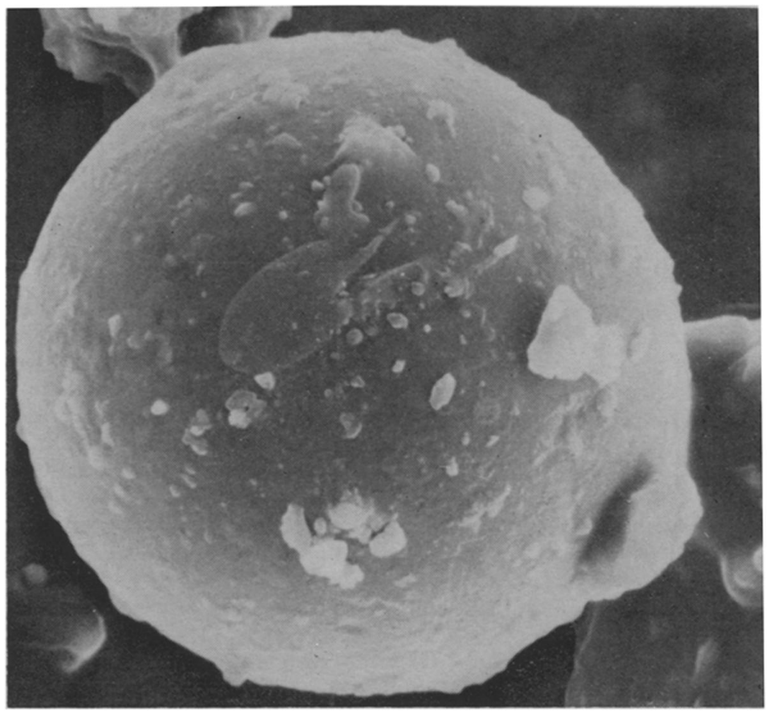
Scientists hold a landmark session

The detailed analysis of Apollo 11's lunar hoard answered no cosmic questions but it produced a flood of information



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Spherical shape of moon particle implies prior melting.

They ran after one another in the halls. They buttonholed one another in stair wells, on street corners, in hotel lobbies and at meals. Abstruse graphs, charts and notes passed from hand to eager hand like the most feverishly desired bubble-gum baseball cards. "I think," said Dr. Gene Simmons, chief scientist of the Manned Spacecraft Center, from the midst of the excitement, "that this meeting may well prove to be a landmark meeting in the history of science."

The attraction, drawing almost 1,000 scientists from 10 countries to the Apollo program's home town of Houston, was the moon. For a frenetic three months, 142 principal investigators and their colleagues have been racing through exhaustive studies of tiny bits of lunar material brought back by Apollo 11, in an effort to unravel the moon's elusive secrets: when, where and how it was born, how it has evolved—and simply what it is like.

For most of the researchers, the pressure has been unprecedented. The need to feed the scientific data back into the Apollo program, as well as to get it into circulation in the scientific community at large, has driven investigators to compress months or years of research into 90 days. In addition, says Anthony J. Calio, director of science and applications at the National Aeronautics and Space Administration center, the scientists feel so competitive on the subject that there has been what amounts to a self-imposed moratorium on the letters and other personal communications by which researchers in related fields usually keep up with the state of their art.

Even without such competition, the lack of time would have kept discussion down. "Communication!" says Dr. Edward Chao, head of a four-man team studying shock forces involved in the creation of lunar materials, "We hardly even have time to talk in the halls. There's too much to do."

Dr. Chao is not the only lunar scientist to have felt the pressure.

"You can play around for a year in here with your microprobe," says University of Chicago crystallographer Dr. Joseph Smith, "and still not solve all the problems."

"I wish," says Dr. Edward Anders, also from Chicago, "that NASA would let us have a three-month moratorium on experiments, and let us just closet ourselves in our offices."

But the data arrived at Houston—almost too much.

Most of the findings overlapped to a large degree; a good deal of sifting will be needed, for example, just to settle on a single list of the elements contained in the material, since they were measured by so many different methods. "When one group of techniques is brought to bear," says Dr. James R. Arnold of the University of California at San Diego, in La Jolla, "things appear one way. Another group, another way."

As a result, the best-attended sessions of the meeting were not the individual presentations, but panel discussions in which four or five lunar theorists could attempt to sift the overkill of evidence in a meaningful way.

Many researchers confirmed that the moon is approximately as old as the earth, about 4.6 billion years, and there were overwhelming indications—lack of water and shortage of volatile elements—that heat played a major role in forming the lunar rocks.

But the key question of the moon's origin—whether it was once a part of the earth, was formed separately from the same condensing mass or is a captured visitor from elsewhere in the universe—remained a subject for speculation.

The fact that the relative abundances of oxygen 16 and oxygen 18 isotopes seemed to match those in earthly rocks suggests to University of Chicago geochemist Dr. Robert N. Clayton, and others, that the earth and moon at least formed in the same part of the solar system.

On the other hand, Dr. Anders found relative shortages of certain trace elements such as bismuth and thallium, even compared to ocean-floor basalt, the portion of earth that most resembles lunar material. This suggests to him that the earth and moon were separate when they went through the process of differentiation: the mechanism by which light elements tend to float and heavy ones to sink in molten material. The moon's heavy elements, called siderophiles (SN: 12/20, p. 573), are at the lunar core, Dr. Anders believes, rather than at the earth's core where they might be if the moon had been ripped from the side of the still-molten earth.

Other elemental abundances confused the picture further. The oxygen-to-silicon ratio, one researcher reports, is very similar to that in earthly basalts. But the zirconium-hafnium ratio, says another, is only one-fourth to one-half of the earth's.

And when the moon dust settled after four days of almost unprecedented scientific excitement, it be-came clear that lunar theorists by now have so much data that some believe that none of the three best known ideas of lunar origin will do.

The closest-running fourth is one supported by Prof A. E. Ringwood of the Australian National University in Canberra. In the latter stages of the earth's condensation, he believes, a massive primitive atmosphere was developed with temperatures high enough to evaporate selectively most of the silicates falling upon the earth. While the silicates were still aloft, the young and still forming sun reached a point at which its condensation provided enough heat to dissipate the rest of the atmosphere, leaving "an assemblage of planetesimals" orbiting the earth, like a much more dense version of Saturn's rings. These in turn condensed to form the moon.

No new elements were discovered in the painstaking investigation, most of which will continue until the samples must be returned to NASA about April 1. But several minerals unknown to exist naturally on earth were found by various investigators.

Dr. Smith's team and several others found traces of a mineral described as an iron analogue of pyroxmangite. The mineral, $FeSiO_2$, has been created in the laboratory but is not known to occur naturally.

Many of the researchers used more than one type of analysis on their samples, minuscule though they often were. In at least one case this led to the discovery of another new mineral. Dr. Paul Ramdohr of the Max Planck Institute for Nuclear Physics in Germany found, using optical emission analysis, what he took at first for kennedyite, a relatively common mineral in acid basalts. A second look, using electron microprobe analysis, revealed it to be something new. The unnamed mineral is a titanium-iron-zirconium silicate with small concentration of calcium and yttrium and lesser amounts of eight other elements including aluminum and sodium.

Still another mineral was found by Dr. Peter M. Bell of the Carnegie Institution of Washington, who referred to it as magnesian ferropseudobrookite. Its formula, approximately, is described as $Fe_{0.5}Mg_{0.5}Ti_2O_5$.

One of the most controversial items in space research has been tektites, bits of black, glassy material found by the thousands on earth and believed by some—notably Dr. Dean Chapman of the space agency's Ames Research Center in California—to have originated on the moon. Dr. Chapman, in fact, has gone so far as to reconstruct their hypothetical path to a particular ray of the crater Tycho (SN: 7/5, p. 6). But the Apollo 11 findings suggest that the mysterious globules are in for more hard times.

Dr. Gerald J. Wasserburg of California Institute of Technology, after mass spectrographic analyses of his lunar samples, concluded that it is "almost impossible" for tektites to have come from the moon. Dr. John A. Philpotts of the Goddard Space Flight Center studied the relative abundances of 13 elements and agreed that the lunar crust seems far different from tektites and, indeed, more like the continental crust of earth itself.

Dr. G. G. Goles of the University of Oregon went even farther. "If I wanted to design a material as unlike tektite as I could possibly do," he told the meeting, "I couldn't do better than this."

Not all scientists have ruled out lunar tektites. The glassy particles do not resemble the basaltic maria, agrees NASA's Dr. John O'Keefe, but that does not eliminate the chance that they could be volcanic ejecta from deep within the moon. "Chapman," he says, "isn't out of business yet."

If origins—of tektites or of the moon itself—seem to be the most elusive items on the agenda, the scientists nonetheless were able to begin filling in many pieces in the picture of what has happened to the moon since it was formed.

Adding up several kinds of evidence, primarily including relative abundances of different strontium isotopes, Dr. Wasserburg concludes that however the moon was formed, it was born within some 10 million years of the rest of the solar system. If it was not formed separately, but was ripped from the side of the earth in some great cataclysm, he says, it was still in the first 200 million to 300 million years of the history of the earth-moon mass.

Dating of the rock samples by several methods also suggests that there may have been several major heating events—eruptions from within or huge meteor impacts—in the moon's early history. The biggest appears to have come about 3.65 billion years ago. At that time, Dr. Wasserburg hypothesizes, the crust of the moon may have been molten to a depth of as much as 60 miles, producing many of the solid, igneous rocks brought by Apollo 11.

There are also unearthly erosion processes at work on the moon, including the constant bombardment by micrometeoroids. Dr. Robert Walker of Washington University in St. Louis estimates that this wears down the lunar rocks at about one millimeter every million years. In fact, estimates Dr. Anders, about two percent of the lunar soil consists of the material of the meteoroids.

A more surprising kind of erosion is also apparently going on, and has caused considerable discussion among the moon scientists in Houston.

Rocks lying loose on the lunar surface, says Prof. Thomas Gold of Cornell University, presumably got there by being thrown out of a volcano or kicked loose by a meteor impact. This should leave at least a slight trench in the fine lunar material on the surface, showing the direction from which the rocks came. Yet the trenches are missing.

"We see no such feature on any of the rocks," says Prof. Gold. "It is absolutely clear that a process is taking place on the surface that fills in the trench that must have been around each rock." In that case, he suggests, one would expect to find traces of similar erosion on the rocks themselves, but there are none. "Even for rocks only two inches above the surface, the top is absolutely clean," he says.

The moon is also apparently a much stronger body than the earth. The earth's lithosphere, the rigid layer that withstands most of the planet's stresses and keeps it in a relatively spherical shape, is about 70 kilometers deep. On the moon, says Dr. Frank Press of Massachusetts Institute of Technology the lithosphere must be several times as thick, since it is able to support the moon's subsurface mass concentrations and other irregularities that produce gravitational variations much larger than those that exist on earth.

As for water, the possibility looks just as slim as it did before Apollo 11 went to the moon. Some traces of mica, a mineral form containing some trapped water of crystallization, have reportedly been found. But beyond a few such minor signs, the moon appears to have been dried out by whatever giant heating event caused the melting from which most of the rocks were formed. Says Dr. Harold Urey of the University of California at San Diego in La Jolla, once a strong believer in the existence of some form of water on the moon, "There has been no surface water present on the moon at all. That's my conclusion."

Strange and alien as the moon appears, it could be providing an indication of the far distant future of earth, suggests Dr. J. A. Wood of the Smithsonian Astrophysical Observatory in Cambridge, Mass. Once the earth's internal heat has died down, as it is likely to when the radioactive elements that provide much of the energy have decayed into lead, it could become a similarly inanimate body. Its surface features would then change much more slowly, acted upon only by differential heating from the sun. □