

The moon: major questions still remain

With the first lunar sample conference already history, the scientific study of the moon is merely beginning

by Kendrick Frazier

Now that all the scientific papers on the Apollo 11 moon rocks have been reported to the research community, it is clear the moon retains much of its essential mystery. The imminent formal publication of the findings, in a special issue of the journal *SCIENCE*, following by only a few weeks their initial announcement at the landmark four-day session in Houston (SN: 1/10, p. 33), tends to impart an air of finality that does not exist.

Most of the 142 principal investigators plan to continue their studies for the next few months, sifting their data, seeking correlations, refining interpretations. As Dr. Gene Simmons, chief scientist for the Manned Spacecraft Center, said at the end of the conference, "There will be many revisions in the coming months of the things said this week."

And comparison with detailed studies this year of rocks from Apollo 12 and 13 is expected to further modify the scientific findings from Apollo 11. All the Apollo 11 investigators have been invited to continue their work with the samples from Apollo 12 and 13, and, as one of them put it, "I don't know of a single one who has turned down the opportunity."

Despite the many uncertainties that still abound, the Houston meeting and the three-month period of frenetic laboratory activity it climaxed will go into scientific history books and memoirs as a special phenomenon, a unique period in the lives of the exuberant investigators.

Dr. Robert Walker of Washington University in St. Louis tried to describe his emotions: a combination of physical exhaustion, intellectual excitement and complete astonishment that, "We're really here. . . ."

"I'll make a bet," he told his colleagues during a rare moment of relaxation at the conference, "that not many

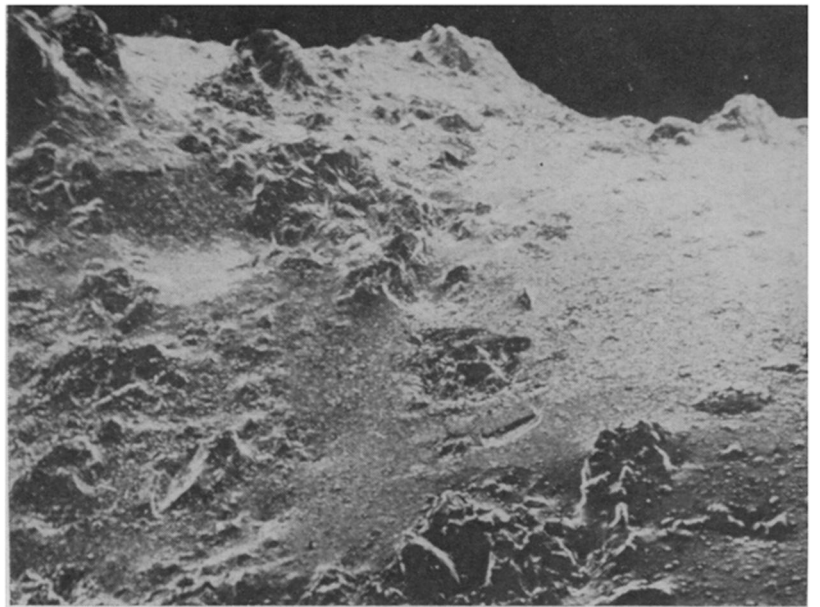
of you a year ago September really honest-to-God believed in your heart and soul . . . that a year later you'd honest-to-God have the samples in your labs."

It was an extraordinary time for the investigators. The historic importance of the activity and the pace imposed by the conference deadline, as well as the camaraderie among members of the teams, planted the seeds of future nostalgia in all the participants. It was not uncommon, said Dr. Walker, to get into a lively discussion at the laboratory on Sunday and have one person interject, "But the observation I made last night . . ." and have someone else top it with, "Yes, but the ones we made this morning. . . ."

Every participant will have a favorite story about the period. Dr. Walker tells of a scream from a woman investigator who had just peered into a microscope at one of the lunar samples left in his office for a few days. "It's a dead bug!" she exclaimed. Dr. Walker and his colleagues raced to the instrument and found she was wrong. It was not a dead bug but a live one, waving its antennas at the assembled audience. The carrier was quickly identified as the laboratory's canine mascot, sitting in the corner scratching.

The purpose of the meeting, however, was not to tell funny stories but to report findings of the scientific study of the first samples of another object in the solar system ever returned to earth by man, and to try to draw whatever conclusions might be possible about the origin and history of the moon.

The most important finding was perhaps the least surprising one: the pinpointing of the age of the moon at 4.6 billion years, nearly identical to the known age of the earth and of the solar system itself as shown by the dating of meteorites.



S. O. Agrell

Microminiature lunar landscape is revealed on sample.

The age determination comes from various types of analysis of the fine lunar soil. But the age of the igneous rocks brought back from the Sea of Tranquility by the Apollo 11 astronauts turns out to be a billion years younger, about 3.6 billion years. This is the time span not from the initial formation of the components of the rocks, but from the crystallization of the rocks themselves, when they locked into their final, permanent composite mineral structure.

This is a tantalizing, if incompletely understood, clue to the moon's early history. It means that some major event apparently occurred on the moon about 3.6 billion years ago, producing enough heat to cause widespread, deep melting and differentiation of the rocks now found on the surface.

The crucial question is whether the source of the heat was internal or external. Internal eruptions causing general melting can be a result of the initial heat imparted to the moon by the gravitational energy of the material that accumulated to form it, or of the decay of radioactive minerals in the interior. There are a number of sophisticated computer calculations of the temperature history of the moon. They show that, depending on what one assumes for the initial temperature and radioactivity content of the moon, a period of intense melting could occur at practically any time in the last 4.6 billion years.

But the possibility also exists that the melting of the moon's upper layer was caused by a massive general bombardment of meteorites about 3.7 billion years ago. An event caused either by meteorite impact or internal heating could have melted a significant portion of the moon, says Dr. Gerald J. Wasserburg of the California Institute of Technology.

If it was due to a general meteorite

KEEP PACE WITH SPACE AGE! SEE MOON SHOTS—LANDINGS, SPACE FLIGHTS, CLOSE-UP!

AMAZING SCIENCE BUYS

for FUN, STUDY or PROFIT

SCIENCE FAIR HDQRS.

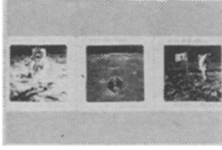
YOUR OWN "MOONDUST"!



Looks like it, feels like it, performs like it. Simulated Moondust authoritatively corresponds in texture, color, overall appearance—even down to minute glass beads. Exclusively prepared by Dr. Thomas Gold—one of original scientists who analyzed actual lunar samples. Fascinating conversational item, great for study, experiments, contemporary education.

Stock No. 41,261Q (1 oz.) \$2.00 Ppd.
 Stock No. 41,262Q (4 oz.) \$7.00 Ppd.

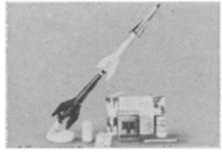
NEIL, BUZZ . . . and you



See close-up for yourself man's greatest adventure. 30 full color super slides vividly show Apollo II journey in amazing detail from "blast-off" to "News Conference." 28 history making shots in between include "Earthrise," cratered lunar landscape, Armstrong descending to lunar surface, man's footprint in virgin soil, classic "portrait-within-a-portrait" of Armstrong's reflection in Aldrin's facemask, Implanting the flag, and much, much more. Really worthwhile . . . even if you don't have a projector.

Stock No. P-41,260Q \$6.00 Ppd.

3-STAGE SOLID-FUEL ROCKET



True ballistic model designed by rocket engineers for real performance. Propelled to amazing speeds by "Fuel"/"Oxidizer" reaction—both non-flammable, non-toxic, harmless to skin. Remote release launch cord. Hours of fun, educational too! Send rocket messages, shoot down kites, race "friends" rockets.

kets. Complete with 3 stages; launch connector base w/adj. support; fuel for 15 launchings; launching string; meas. tank. Instr.
 Stock No. 71,201Q \$7.50 Ppd.

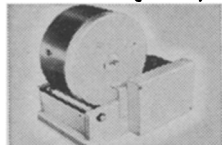
TEACH YOUR 2-YEAR-OLD TO READ!



Psychologists now say that birth to 5 is the mental prime of life—that 80% of a child's intelligence is determined by 4 years of age. Preschoolers not only can read . . . they want to read. Every parent has the wonderful opportunity to help satisfy this monumental desire and capacity to learn . . . and this

Early Reading Kit helps parents help their children. Contains Dr. Glenn Doman's book, "How to Teach Your Child to Read"; Word, Sentence Structure, Phrase and Alphabet Cards (total 162); child's reading book and Graduation Certificate.
 Stock No. 71,187Q \$9.95 Ppd.

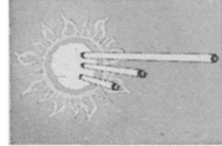
HIGH QUALITY, LOW-COST TUMBLER



Real money-saver for small shops—experimenters . . . cheaper to tumble—finish than machine irregular-shaped metal, plastic pieces, small castings, etc. Many users—remove scale from rolled forged parts—deburr, round off corners, polish angular or cylindrical shapes. Rugged 10-sided rubber barrel—quiet running, twice reg. tumbling action. 6 lb. (4 1/2 pt.) cap. w/continuous duty motor comp. to others selling many times price. 12" x 8 1/2" x 10".

Stock No. 80,096Q \$28.95 Ppd.

FLIP ON THE SUN



Bring 91% of sun's light indoors. Natur-Escent lamps give true color fidelity without distortion. Closest thing to natural light—even use outdoor film indoors without door gardening. Reduces eyestrain, fatigue. Long tube life, fit standard fixtures.—Sets of 4.

No. P-71,151Q 15W., 18" L
 No. P-71,152Q 20W., 22" L
 No. P-80,124Q 40W., 48" L

ENCAPSULATED LIQUID CRYSTALS



Amazing new development—appear like liquids but have orderly molecular structures similar to solids. Solutions contained in tiny (20-30 microns) capsules coated on sides of six 8" x 12" Mylar sheets with 6 diff. temp. ranges. Surface changes color according to temp.—cover 66° to 120°F (19°-49°C). No mess. No contamination. Use indefinitely.

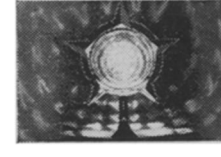
Stock No. 71-143Q \$10.00 Ppd.

DRAMATIC 2' x 3' ASTRO MURALS



Exact black and white reproductions in amazing detail. Choice of 10 famous sky phenomena on fine paper by Colotype process. Great Space-Age decorations, backgrounds, for home, school, office, institutions. Put pinholes in stars, shine light through for fascinating effects. Perfect astronomical atmosphere for parties, dances. Even cut up into pieces for Space-Age jigsaw puzzle. Endorsed by leading professional astronomers. Set of 10—\$75.00 postpaid. Avail. individually (2 listed below) Last Quarter \$7.50 Ppd.
 No. 70,252Q MOON, 14 Days \$7.50 Ppd.

ROTATING MULTI-COLORED LIGHT



Dazzling colors stream endlessly from constantly rotating light. Faceted, transparent globe has lowered drum inside with red, green, blue & yellow stars. Bulb heat rotates drum which projects flickering star points on walls, ceilings, etc. while individual globe facets present constantly changing array of brilliant colors. 9 1/2" star—approx. 12" high on bell-shaped base. Surprisingly light. For table, TV, fireplace—even top of Christmas tree or other display.
 Stock No. 71,000Q \$6.00 Ppd.

3" ASTRONOMICAL TELESCOPE



See the moon shots, orbits, stars, phases of Venus, planets close up. 60 to 150 power. Aluminized and over-coated 3" diameter f/10 primary mirror, ventilated cell. Equatorial mount with locks on both axes. 60x eyepiece and mount. Barlow lens. 3x finder telescope, hardwood tripod. FREE: "STAR CHART"; "HANDBOOK OF HEAVENS".

Stock No. 85,050Q \$29.95 Ppd.
 Stock No. 85,051Q 4 1/2" \$34.50 FOB
 Stock No. 85,052Q 6" \$39.50 FOB

BATTERY POWERED GYROSCOPE!



For the first time—have the fun & enjoyment of a gyro without bother of constant string winding & pulling. 5" diam. flying-saucer shaped. Spins on its edge, upsidown, on your head, hanging from a string, drives rocket car, races around a ring—you'll be amazed at its performance. Even flipping switch to off is an experience—speeds up to a blur . . . for almost 3 min. without power. Terrific accessories incl. rocket car, pedestal, 3" diam. orbit ring, ring pedestal, cap, chain, loop, instruct. Batteries not included.

Stock No. 71,181Q \$6.00 Ppd.

NOW! WATER CLIMBS UPHILL



Amaze your friends—loads of fun—perfect for Science Fair. Water actually flows up side of glass & siphons freely into other container. To stop flow—cut with scissors—watch it snap back. Secret's in special additive with long molecular structure—1/2 tsp. to glass. Friction reducing additive has industrial, agricultural uses—a pinch makes gold fish swim faster. 3 oz. can treats 84 pints.

Stock No. 41,086Q \$2.00 Ppd.

INTRIGUING LOW-COST MOON MODEL



Exciting outer space display and conversation piece. Exact replica, 30,000 formations—peaks, craters, Ocean of Storms, etc.—all in relief. Scaled to size. Accurate distance relationships. Proper lighting shows moon phases; "black light" produces startling effects. Tough, washable plastic. Three colors. Far side blank—can be used for space data. Excellent gift item. 12" dia., wt. 3/4 lb.

Stock No. 70,515Q \$12.50 Ppd.

MAIL COUPON FOR GIANT FREE CATALOG

148 Pages! More than 4,000 UNUSUAL BARGAINS!

Telescopes, microscopes, binoculars, magnets, magnifiers, prisms, photo components. Mail coupon for FREE Catalog "Q," EDMUND SCIENTIFIC CO., 300 Edgemoor Building, Barrington, N.J. 08007.

Name _____
 Address _____
 City _____ State _____ Zip _____

. . . moon

bombardment, the implications multiply. The oldest rocks found on earth, for instance, crystallized about 3.6 billion years ago. Since the earth presumably would have been subjected to the same massive meteorite barrage that affected the moon, several scientists, including Dr. Wasserburg, suggest that the impacts might also have erased the earth's geological record from 3.6 billion years on back.

There is no evidence, other than this coincidence in time, for such a mutual catastrophic event reworking the surface of the earth and moon simultaneously. But although caution was usually urged, speculation was not always discouraged.

Dr. Robert Jastrow, director of the Goddard Institute for Space Studies in New York City, observed that no primitive life forms older than about 3.4 billion years have been found on earth (SN: 11/15, p. 445). He suggests that such a major meteorite bombardment might have destroyed pre-existing life forms and that life on earth actually once dated from closer to the planet's origin 4.6 billion years ago than is now presumed. "Chemical evolution," he says, "may have begun over again."

Evidence pointing away from such an event may already be in hand in the form of the Apollo 12 rocks, which have in preliminary study been dated at about 1 billion years younger than those from Tranquility Base. This preliminary data, says Dr. Frank Press of the Massachusetts Institute of Technology, "does not prove, but suggests that there may be nothing unique about the 3.6-billion-year figure either here on earth or on the moon. It indicates that we will have other kinds of dates that will show up as we go to different places."

Much of the information in hand as a result of Apollo 11 concerns lunar mineralogy and petrology. The returned surface rocks consist largely of the minerals pyroxene, ilmenite and plagioclase, with lesser amounts of such minerals as olivine, troilite and cristobalite. These same minerals with somewhat analogous textures are common in basic igneous rocks found on earth.

One major difference, though, is in the proportions of the minerals. In the lunar samples the pyroxene is most abundant. In terrestrial basalts plagioclase commonly equals or exceeds pyroxene in abundance. Both minerals are silicates, composed of silicon and oxygen in combination with certain metals.

A second striking difference is the abundance of ilmenite, a mineral rich in titanium and iron, reflecting the

ORDER BY STOCK NUMBER • OPEN ACCOUNT TO RATED FIRMS • MONEY-BACK GUARANTEE

EDMUND SCIENTIFIC CO. 300 EDCORP BUILDING

BARRINGTON, NEW JERSEY 08007

Circle No. 125 on Reader Service Card

large concentrations of those elements found on the moon. The lunar rocks are also totally water-free and lacking in ferric ions, iron atoms with a valence of plus 3, whereas in terrestrial basalts both ferric iron and combined water commonly approach or exceed one percent of the weight.

Basalts from the ocean crust, ridges and rises on earth contain approximately the same amounts of magnesium, calcium, potassium, phosphorus, uranium, thorium, yttrium and ytterbium as do the lunar samples, but far less iron, titanium, barium and zirconium, and higher concentrations of silicon, aluminum and sodium.

Thus even when compared to their closest analogue on the earth, the moon rocks show significant differences, indicating a decidedly different history of geochemical evolution. Variations in ratios such as aluminum/calcium, silicon/magnesium, sodium/potassium and in amounts of titanium and phosphorus point up the diversity of the igneous processes that have produced the rocks of the earth and the moon in their present form and composition. The major process in operation on the moon seems to be the crystallization of silicate melts in a highly reducing (oxygen-depleted) environment.

These essential differences lead Dr. A. E. J. Engel of the Scripps Institution of Oceanography and others to emphasize that a variety of igneous processes are probably responsible for formation of all planetary igneous rocks. Deciphering earth-moon origins will not be easy.

The moon promises to be a rich and varied place for scientific study of the solar system, with many secrets yet to be unfolded and with many pitfalls for the incautious investigator who tends too casually to apply his earth-based assumptions to understanding the characteristics and history of the similar but different lunar surface.

"It seems to me that lunar geology is something which is quite distinct," says Dr. S. O. Agrell of the University of Cambridge, England. Clinging to earthly geology is like wearing a special kind of blinders, he says, which do not allow the scientist to be imaginative enough.

Dr. Harold Urey of the University of California at San Diego suggests one further step. Concerned that scientists studying the moon need to become more intellectually adaptable to new ways of thinking, he proposes "that we consider the study of the moon selenology and not geology. It is important that we realize we are working with a distinctly different object." □

January 24, 1970

Bausch & Lomb StereoZoom Microscopes rate Summa Cum Laude



Instructors of science classes using StereoZoom Microscopes for examination and dissection of living materials and preserved specimens, and general lab requirements rate these instruments at the top of the list. To be sure your students receive the most effective instruction, choose Bausch & Lomb StereoZoom Microscopes.

You will also be making the wisest use of your dollars. StereoZoom Microscopes are the easiest to use, least complicated, professional quality three dimensional microscopes you can buy. Their optical performance is outstanding. High resolution, true stereopsis, flatness of field are assured. Mechanically, they are built to withstand years of the sometimes careless treatment they get from students. There's a model exactly suited to your curriculum needs.

Find out about Bausch & Lomb StereoZoom Microscopes. Write today for our new catalog 31-15 and our free demonstration offer.

StereoZoom Reg. T. M. Bausch & Lomb

BAUSCH & LOMB

SCIENTIFIC INSTRUMENT DIVISION

20823 Bausch Street, Rochester, N. Y. 14602
Circle No. 124 on Reader Service Card