SCIENCE NEWS OF THE WEEK

Rockfest VII: Latest Word on the Early Moon

The moon may not be alive and well—the state of its innermost core is still an open question—but the moon-watchers are thriving. Last week more than 700 of them met at the National Aeronautics and Space Administration's Johnson Space Center near Houston for their annual conference on lunar rocks and related data, an event that has come to be informally known as the "rockfest." One might expect that after seven such gatherings, interest would have waned. If anything, Rockfest VII was more animated, contentious and interesting than last year's session, and 1975 was a year in which, out of some 1,400 requests for information from NASA's National Space Science Data Center in Maryland (which includes voluminous planetary data as well), 600 were concerned with the Apollo program's gleanings from the moon. Only about 10 percent of the 844 pounds of Apollo moonrocks have even been studied, in fact, and new interpretations are still appearing at such a pace, according to Dieter Heymann of Rice University, that they are often "outmoded by the time they get into print."

Photo by Harrison Schmitt/NASA

Apollo 17 astronaut Eugene Cernan nears a breccia from the early moon.

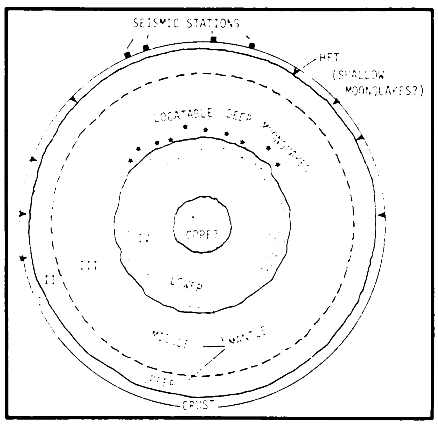
The broadest questions—where did the moon come from?—are still unanswered, says Rockfest VII co-chairman Larry A. Haskin of JSC, "but the constraints are getting tighter." A lot tighter. While the actual age of the moon remains undetermined somewhere around 4.6 billion years, researchers at the California Institute of Technology have made an unusually strong case for a less dramatic but nearly as significant date: the end of the moon's initial differentiation—the original "setting" of the lunar material.

The evidence is in the form of six rocks, three of them from the craggy lunar highlands and three from the igneous material of the moon's mantle. All six (out of six studied, according to Fouad Tera of Caltech) point to a single date, 4.42 billion years ago plus or minus 40 million years, for the implantation of the radioactive elements from which they have been dated. Three of the rocks fall directly on that date; the other three (and possibly a fourth, still being tested) show later crystallization sequences, or isochrons, that intersect there. Using a precise uranium-lead method capable of dating fragments as small as 10^{-12} gram, Tera and colleague Gerald J. Wasserburg have established at least a minimum age for the primordial lunar hard rock—and it may be older still.

Such significant moonrocks have sometimes been given names—a crystalline anorthosite officially known as 15415 became "The Genesis Rock;" a basalt was christened "Great Scott." At Rockfest VII, holocrystalline breccia 79215 might appropriately have been dubbed "The Survivor." What it survived, according to Charles E. Bickel of San Francisco State University, was a cataclysmic meteorite bombardment about 3.9 to 4.0 billion years ago that many scientists believe accounted for much of the cratering on the lunar surface. Most lunar breccias were brecciated, or crushed, during the cataclysm, Bickel says, so that their original compositions became inextricably intermixed. The Survivor, however, appears to have been brecciated shortly after its formation in the moon's earliest days, when the smaller number of impacts gave it a fighting chance to retain its compositional integrity. Thus, its matrix contains clusters of adjacent grains of olivine (as opposed to a random olivine-pyroxene mixture), suggesting that it has preserved a "memory" of its original grain size and composition. The odds of its surviving the great bombardment were small indeed according to Bickel, who studied the rock with Jeffrey L. Warner and William C. Phinney of JSC. "A few people in Hiroshima survived the bomb," he says, a potent analogy but "quite close in terms of the vigor of the destruction that was going on."

Lunar scientists do not view the great bombardment only as a destroyer, however. It has provided a rich range of examples of cratering mechanics that have even caused geophysicists to reinterpret a number of features on the earth. One discussed at Rockfest VII was Canada's huge Manicouagan crater, now largely accepted to be the result of a titanic impact. Until as recently as five years ago, says Robert Pepin of the Lunar Science Institute in Houston (and Rockfest VII's other co-chairman), it would have been called "the remains of Manicouagan Volcano."

Comparisons between the earth and the moon, in fact, may have become easier with the Rockfest report by Marcus G. Langseth, Stephen J. Keihm and K. Peters of Lamont-Doherty Geological Observatory, based on instruments left by Apollo 15 and 17 astronauts, that the lunar heat flow is little more than half its previously estimated amount. This means that there is less heat coming out of the moon, which means that there is less uranium and other heat-producing elements in the lunar lithosphere, perhaps only 35 parts per billion, by one estimate, instead of 60. Lunar researchers, says M. Nafi Toksöz of the Massachusetts Institute of Technology, now need rationalize only a twofold lunar enrichment in certain uranium-associated minerals rather than fivefold. The moon, he says, now appears to be "more like the earth than was ever thought about before." Because the important early rocks dated by Tera and Wasserburg seem to represent more uranium for the total moon than the reduced heat flow mea-



Nakamura, Latham, Dorman/Univ. of Texas

A thick lithosphere, but what core?

surements would suggest, Tera proposes that the uranium may be concentrated more closely to the surface than has been supposed. This fits nicely with what seemed to be one of the general conclusions of many Rockfest VII participants: that the lunar lithosphere is thick indeed, encasing whatever lunar core may exist in a rigid shell perhaps 1,000 kilometers deep. More important, perhaps, is that the more nearly terrestrial element ratios allowed by the reduced heat-flow data do not require the moon to have formed at a great distance from the earth.

Comparisons between the moon and the earth and other terrestrial planets, in fact, were a significant part of this year's conference. Mark J. Cintala, James W. Head and Thomas A. Mutch of Brown University, for example, calculated the differences in crater shapes for the moon, Mars and Mercury. On Mercury, Cintala pointed out, craters of a given size are shallower than they are on the moon, in part because the surface gravity of Mercury is more than twice that on the moon. But Martian craters tend to be shallower still, and the gravity of Mars and Mercury differ by barely 3 percent, so there must be other factors that affect the hole produced by an impacting meteorite. Because Mars and Mercury are at different radial distances from the sun, he suggested, their impact velocities, even with similar gravity, could vary by as much as 30 percent. Atmospheric differences would make a difference, as might variations between the two planets' subsurface layering (providing a harder or softer floor to absorb impact energy).

Charles A. Wood, also of Brown, adds that basins—large craters with concentric ring structure—follow a regular progression from Mars inward to Mercury, both in the total number per planet (19 on Mars, 33 on the moon, an estimated 100 on Mercury) and in the number for a given surface area. That they are so different in number for Mars and Mercury is further evidence that other, nongravitational influences were at work.

Survivor and Genesis rocks notwithstanding, a major goal for planetologists is to identify "pristine surfaces"—areas where portions of a planet's original outer layer have not been radically altered by impacts and volcanism. Earth presumably has none; tectonics and erosion have seen to that. The same may be true for Mars, but there are promising signs in Mariner 10's photos of Mercury. Vernon R. Oberbeck of NASA's Ames Research Center and R. H. Morrison of LFE Corp. in California have carried out laboratory studies showing where the fall of material tossed out by an impact would be at a minimum, and Oberbeck told the Rockfesters that a few such areas—with a minimum of small craters between the big ones—may exist on the moon. One appears to be a region in the south-central lunar highlands near Hipparchus. □

O+ in eggs: Getting past the hollow ball

The "gee-whiz" approach to biology went out with Buck Rogers and his magic flying machine. The "wonders of this" and the "mysteries of that" began to melt away when biologists turned high-powered microscopes and biochemical techniques on the living cell. There is still at least one life process, though, that deserves the term "amazing": It is the series of events that begins with one egg cell and ends with a young organism composed of several trillion. Embryologists are still baffled by the early events in this series, specifically how the egg cell is "activated" and its genes suddenly turned on and directed toward the production of differentiated cell types. One embryologist, a doctoral candidate at Indiana University, has now unraveled a bit of this "amazing mystery."

Ann Janice Brothers reports a detailed study on the "*o*+ substance" from the Mexican axolotl in the March 11 NATURE. The axolotl is a strange looking, neotenous salamander that never loses its feathery gills or tail fin during maturation. The "*o*+ substance" is one or more proteins that seem to be necessary for egg cell activation past the early stages of development. These proteins are laid down in the cytoplasm of egg cells during oogenesis (egg production) in the normal adult female axolotl. Abnormal females with a mutation in the gene pair that codes for synthesis of these *o*+ proteins cannot produce the proteins or stock them in the egg cells, and thus make defective eggs. These defective eggs stop dividing a day or so after fertilization and never form normal axolotl young. Normal eggs, with the *o*+ proteins, continue to divide.

Two Indiana University embryologists made the initial discoveries that led to Brothers's experiments. R. R. Humphrey found the mutation in the female axolotl, and Robert Briggs discovered that the *o*+ proteins are laid down in the egg cytoplasm before fertilization. But Brothers, for her doctoral dissertation, did an extensive series of nuclear transplantation experiments to pinpoint the role of the *o*+ proteins in egg cell activation.

Brothers took nuclei from normal axolotl eggs and transplanted them into mutant eggs (without *o*+ protein). Nuclei removed from normal cells during the early blastula (hollow ball) stage did not induce full development of the mutant eggs. But nuclei removed during the mid-to-late blastula stage did induce full development of the mutant eggs to adult axolotls. This shows, Brothers says, that the *o*+ proteins in the cytoplasm begin to work only during the middle or late hollow ball stage, just in time for the gene activation that directs the next and subsequent stages (gastrulation and organ formation) in the growing embryo.

The implication is strong that this *o*+

Adult Mexican axolotls, grown from egg cells with transplanted nuclei, to show that o+ proteins must be present for normal development.

Indiana University/Lawrence M. Lawrence

substance somehow interacts with the embryonic genes during the blastula stage, perhaps to "turn on" the genes needed for continued development. "But," Brothers says, "we don't have direct evidence of this interaction yet." The next step, she says, will be to isolate and characterize the *o*+ proteins, then to trace their movements within the cell with fluorescent antibodies. These will adhere to the *o*+ proteins and should make it possible to detect whether or not they enter the nucleus during mid-to-late blastula stage and form a complex with some of the chromosomes—an indication of gene activation. It is also not clear yet whether this *o*+ system works only in axolotls. Briggs's earlier work, however, shows that a wide variety of amphibians have an egg activating substance. □

Laser enrichment: Companies vying

In spite of Marx, Engels and Lenin, the wave of the future with regard to the one socialized industry built in the United States, uranium enrichment for reactor fuel, seems to lie with the corporations of bourgeois capitalism rather than the proletarians of the federal bureaucracy. As long ago as 1972 the Reynolds Metals Co. filed an application with what was then the Atomic Energy Commission for a license to build a uranium enrichment plant in Wyoming. Reynolds has since dropped the idea, but at least three other private enterprises are now asking for a piece of the enrichment action: Exxon, Garrett Corp., and Centar Associates, the latter described as "a joint project of ENI Nuclear Co., owned by ElectroNucleonics, Inc., and Arco Nuclear Co., owned by Atlantic Richfield Co."

For use as reactor fuel (or as bomb charges) natural uranium must be processed so that the concentration of the fissile isotope U-235 is increased com-