Research Notes

The Moon Revealed—I

The moon, says Gerald Wasserburg, professor of geology and geophysics, is 4.6 billion years old, and the lava that flowed out on the surface of the Sea of Tranquillity is one billion years younger. Wasserburg, one of three Caltech principal investigators for Apollo 11 lunar samples, told NASA's first Science Conference on Lunar Materials that if the lava was caused by the bombardment of great meteorites (instead of internal melting and volcanoes), then the earth's surface, too, must have been heavily bombarded by them. This could account for the absence on the earth of a geologic record prior to 3.6 billion years. Wasserburg also told the meeting of Apollo investigators that:

At least the outer 62 miles of the moon have been molten. If the moon originally was a part of the earth and then separated from it, this must have happened in the first 300 million years in the history of the solar system.

Tektites cannot come from the moon.

There are single, individual rocks on the moon's surface that are 4.4 billion years old, which is still 200 million years younger than the age of the moon. These rocks may possibly come from the lunar highlands.

The apparent lunar age (4.6 billion years), said Wasserburg, was determined from analysis of lunar soil, which is the result of mixing of different rocks and of melting. Some of the melting was caused by meteorites, and iron meteorites and glass containing little balls of iron meteorites were found on the lunar surface.

The group's samples included a variety of rocks covering 700 million years of time. A complicated geologic evolution in the formation of different rock bodies must have taken place in the first billion years of the moon's history.

The surface of all rocks and grains of soil are covered with pits as small as 10 microns in diameter, the centers of which are glass surrounded by radial fracture zones caused by bombardment of the lunar surface with tiny, high-velocity dust particles. Wasserburg also said that the solar wind's gasses have peculiar isotopic composition and must be related in some important way to the atmosphere of the earth.

The research was done by a Caltech group (which calls its laboratory the Lunatic Asylum) composed of scientists from the United States, Greece, Spain, Switzerland, Germany, Egypt, and China. Associated with Wasserburg in the work were co-investigators Arden Albee, professor of geology, and Donald Burnett, associate professor of nuclear geochemistry.

The Moon Revealed—II

A second principal investigator—Samuel Epstein, professor of geochemistry—reported that studies of the isotope ratios of oxygen, silicon, hydrogen, and carbon showed that the rocks formed at temperatures (1,150 to 1,340 degrees Centigrade) a little higher than the temperatures at which earth rocks formed.

The bulk of the oxygen and silicon isotope ratios of lunar basalts are identical with terrestrial basalts, but lunar glass, breccia (hardened aggregate of surface debris), and dust are slightly enriched in the heavier isotopes. This suggests either that sublimation-evaporation took place at some high temperature or that there is a source of material enriched in the heavier isotopes of oxygen and silicon elsewhere on the moon.

Epstein and his co-investigator, Hugh Taylor Jr., professor of geology, also found that the lunar dust and breccia contain hydrogen from the solar wind, and this hydrogen is very low in deuterium content (less than one-tenth of terrestrial abundance).

The carbon in the dust and breccia is considerably enriched in carbon-13 and is unlike any reduced natural carbon found on earth or in meteorites. This enriched carbon may come in part from the solar wind or may have resulted from the process involved in formation of the lunar material. Epstein and Taylor say it is unlikely that terrestrial contaminants, such as grease or rocket fuel, were a factor since that source of carbon is low in carbon-13.

The Moon Revealed—III

A third investigator for Apollo 11, Leon T. Silver, professor of geology, told the conference about his studies of the abundances of lead, uranium, and thorium isotopes in the lunar samples. He found that the lunar dust contained radiogenic isotopes Pb-206 and Pb-207 in a ratio which suggested an apparent age of 4.63 billion years—as old as anything measured so far in the solar system. A piece of lunar breccia showed an apparent age of 4.60 billion years. Silver cautioned the conference, however, that these ages may be more apparent than real because the dust and breccias are complex mixtures of rocks, minerals, and glasses of uncertain origin, and the isotopes observed are peculiar composites which cannot be uniquely interpreted at this time.

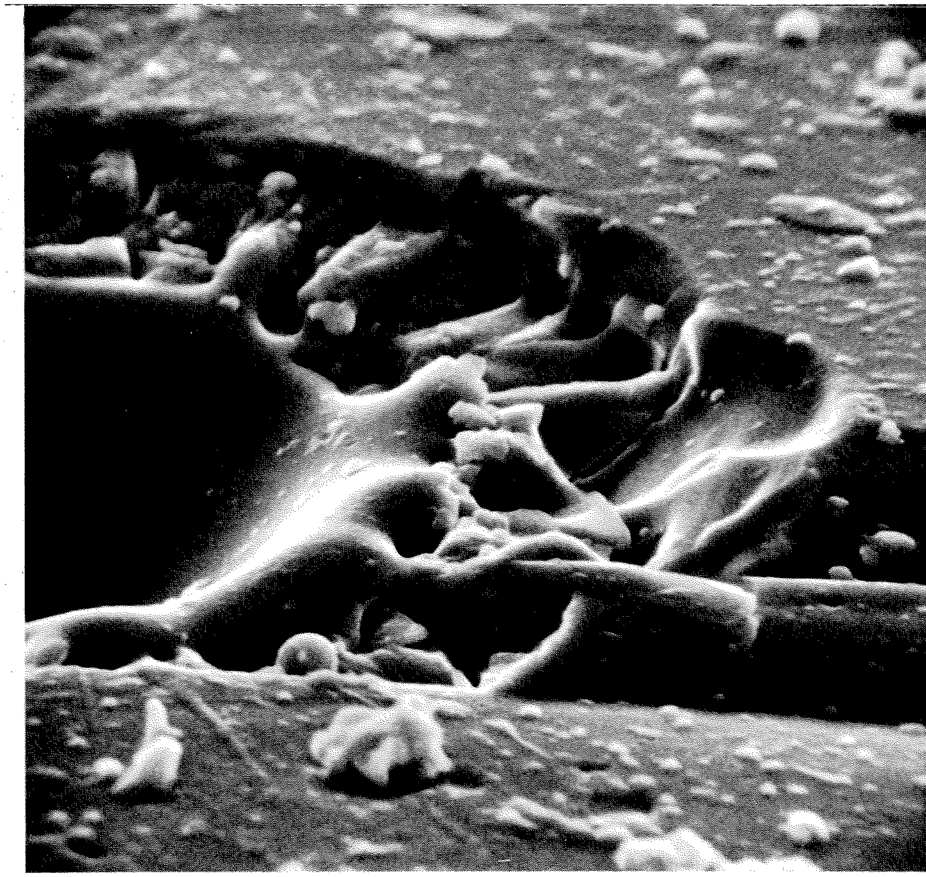
Four fragments of rocks, all from the same site, showed apparent ages between 4.1 and 4.2 billion years. Another investigator, using the same "geologic clock" on a fragment off the same rock as one of Silver's fragments, got almost identical results, but Silver points out that other age-dating techniques give different apparent ages on similar samples, and he doesn't know how to reconcile the discrepancies.

If the four rocks represent sources that have contributed to the dust also, and many data suggest this, then it may be inferred that the dust contains some materials with greater ages than that measured from the dust sample. This would imply an even greater age than 4.63 billion years for some part of the lunar surface.

But Silver, questioning a generally held belief that the moon is 4.5 or 4.6 billion years old, is not convinced that anyone yet knows its exact age. He agrees the moon is ancient—at least 4.2 billion years old—but suspects that all the rocks so far examined came from the same source—just as almost any rocks around Pasadena came, at one time or another, from the disintegrating San Gabriel mountains. The dust, however, shows variations in isotopic ratios that imply a mixed source. Silver wants to see analyses of samples from many other sites, with some independent tests for historical sequence, before he will have confidence in a definitive age of the moon.

The most striking thing he found, and something he thinks is of more interest than the precise age of the samples, is that lead has been separated or fractionated from uranium to a degree never observed in rocks on the earth. This indicates that the lunar processes being studied are very different from modern terrestrial processes, although they may not be so different from processes that occurred early in the evolution of the earth. Studying lunar rocks, says Silver, may be the only way of getting at an understanding of the processes that took place early on the earth.

The mass spectrometer used in Silver's work (called Dulcinea, after Don Quixote's dream girl) was specially built for the moon samples. Ages were determined by measuring the ratios of radioactive materials to their decay products. The "geologic clocks" used were uranium 238 decaying to lead 206, uranium 235 to lead 207, and thorium 232 to lead 208. Assisting Silver in the work were Geraldine Baenteli and Maria Pearson.



Tiny, high-velocity dust particles hitting the moon created pits like this one (magnified about 5,000 times) in the surfaces of lunar materials. The center of the pit is glass.

Place in the Sun

Unlike stellar astronomers, who must search the world for dark, clear skies to peer through, solar astronomers look for bright sunshine and still air. Smoggy Pasadena happens to be a good observing site because the temperature inversion layer that traps smog also results in a relatively non-turbulent atmosphere.

Now astronomers at the Hale Observatories have found an even better location—6,758 feet high in the middle of Big Bear Lake in southern California's San Bernardino Mountains. A new observatory opened there in October, and solar astronomers are already making excellent detailed observations of the sun's structure. Warm air rising from the ground ordinarily causes disturbances in the atmosphere, but at Big Bear the nearly constant daytime temperature of the water surrounding the site makes the air turbulence minimal.

Much of the observing is done with time-lapse movie cameras—invaluable in studying the "metabolism" of the sun as reflected in sunspots, flares, prominences, and shock waves. Exposures are made every five to ten seconds. The telescope barrel actually contains four observing instruments—two for cinematography in different wavelengths; one for a spectrograph to analyze the sun's chemical composition and temperatures; and one for a coronagraph to study the hot region above the sun's surface.

The observatory is 800 feet from shore and includes four acres of land on the lakefront, a three-bedroom dormitory for visiting observers, and a laboratory.

Harold Zirin, Observatories' staff member and Caltech professor of astrophysics, is in charge of research being done at Big Bear. Two observers, an electronics technician, and a machinist work at the site permanently. The equipment was financed by NASA, and the buildings were funded by NSF and the Max C. Fleischmann Foundation of Nevada.

Leukemia and DNA

Although the problems of cancer—its causes and cures—appear to be awaiting advances in the molecular biology of normal cells, the abnormalities of cells are giving researchers new insight into certain types of leukemia. Research by Caltech graduate student David A. Clayton and Jerome Vinograd, professor of chemistry and biology, has disclosed what appears to be a significant link between granulocytic leukemia in humans and an abnormality in the DNA of white blood cells.

The anomaly was found not in the DNA of the nuclei of the white blood cells (where most of the genetic material of the cell is located), but in the mitochondria. These are microscopic structures in the main body (cytoplasm) of the cell that supply the energy for the cell's metabolism.

Normally the mitochondrial DNA is in the form of a small ring five microns in circumference. But Vinograd and Clayton found in the leukemia patients a large percentage of abnormal DNA rings that were of double size (called dimers). The mitochondrial DNA from 14 leukemia patients was studied, and in all instances the double-size DNA rings were found. Significantly, treatment of patients with anti-leukemic drugs substantially lowered the frequency of the circular dimers.

Vinograd and Clayton cannot be sure whether the DNA abnormality is a symptom or a cause of the leukemia. The present state of knowledge about normal cells is not adequate to make possible an immediate understanding of the significance of their finding.