From sun to moon

Circling the earth unshielded by any protective atmosphere, the moon has been bombarded by a constant rain of particles from the sun and from galactic space. The lunar rocks thus contain records of the history of the sun as well as the moon itself.

For some of the scientists who assembled at the Lunar Science Conference in Houston then, the major focus of interest was not the moon, but the sun, or the information about it deposited by both solar flares and the solar wind.

Science's look into the sun's history as written on the moon has not gone beyond a glance at the first paragraph or two. But that brief look has told Dr. James R. Arnold and his colleagues at the University of California at San Diego that in the past 10 million years or so the average flow of protons from solar flares has apparently not changed significantly. At least the flow during that time was no less than the present average rate of about 30 protons per square centimeter per second.

This means that solar events such as flares have apparently been continuing for millions of years much as they are today. "Perhaps that doesn't surprise anybody," says Dr. Arnold, "but I think this is the first direct experimental evidence that this is true."

Such a finding was not as obvious as it might seem. Solar flare emission, says Dr. Arnold, is irregular, and variations on a long-time scale might also be suspected.

The exploration of solar history by the lunar scientists is limited to the length of time lunar rock has been exposed on the surface. Solar particles penetrate only a small distance. A rock covered by even a few centimeters of soil is shielded and thus receives no imprint of a solar particle record.

One general finding from the conference is that the lunar rocks remain on the surface for only a small fraction of their total lifetime; they soon are buried again as the soil is turned over by a continual barrage of meteorite impacts. Some of the rocks, in fact, apparently go through cycles of exposure and burial, and each time they are exposed scientists have a potential window to the solar activity at that time.

The rocks available now have not been on the surface long. They have been exposed only for the last 10 million years or so. What the scientists would like to get would be a variety of rocks that had been exposed to the surface over a range of times. Once those times were determined they could extend the solar record backwards.

Nobody is sure what they would learn about changes in solar activity. "It's anybody's guess as to whether 70 million years ago or 700 million years ago it was very different," says Dr. Robert Walker of Washington University in St. Louis. "My hunch is that it will be."

Not all the evidence told the story of the distant past. An analysis of a relatively short-lived product of reactions from solar particles—cobalt 56—clearly showed evidence of the massive solar flare known to have occurred on April 12, 1969.

In contrast to solar flares, which tend to reach peaks of activity at 11-year intervals, the solar wind sends a continual flow of particles outward into space, at the relatively slow rate of 200 to 300 miles a second.

The lunar rocks contain great abundances of the noble gases, and there was almost complete agreement among the investigators that the bulk of the inert gases have been carried from the sun to the moon by the solar wind.

The composition of argon and krypton in the lunar rocks correlates well with the composition in the earth's atmosphere. But abundances of xenon and neon in the rocks are higher.

One of the more puzzling aspects was the high concentration in the rocks of argon 40. That isotope is produced routinely by the decay of potassium, but the excess abundance of the isotope in the lunar soil is so great that it would imply an embarrassingly high potassium-argon age for the moon—about 7 billion years, a figure no one takes seriously.

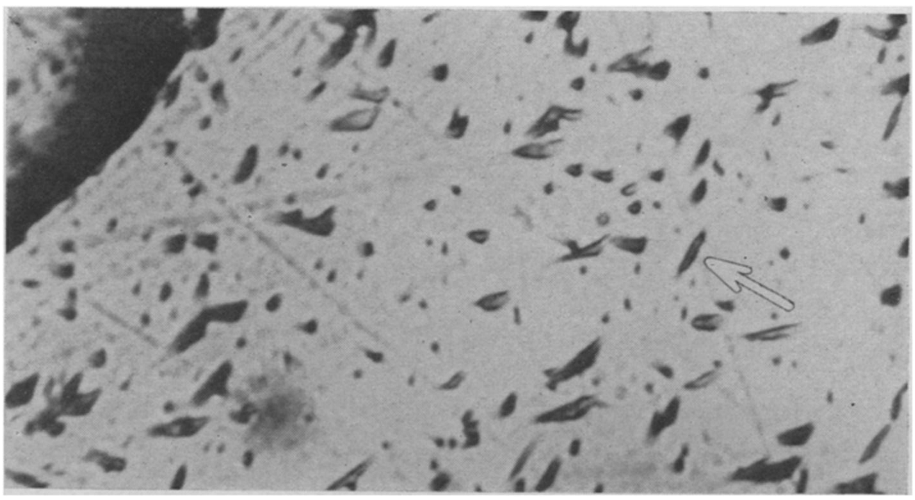
The question is where the argon came from. Although argon 36 is regularly produced by the sun, solar physicists believe that very little or no argon 40 is produced there. One scientist even offered to resign his university position if the abundance proved to be solar in origin.

Dr. Dieter Heymann of Rice University offered a hypothesis that gives the moon as the source of the excess. The investigators have been able to determine that both the argon 36 and argon 40, as well as the other rare gases, entered the particles of lunar dust through their exterior surfaces. This is indicated by the fact that the concentration of gas is larger for smaller grains, which have a greater surface area in proportion to their volume.

Dr. Heymann proposes that the argon 40 in any particular particle was produced elsewhere on the moon by the decay of potassium, worked its way up through the soil as melting took place and was liberated from the surface, becoming part of an extremely thin, transient lunar atmosphere.

Individual atoms of the argon isotopes, in this view, were struck by particles of the onrushing solar wind; the argon was driven down into the grains of dust. Since in this theory the contribution of the isotope from potassium decay comes from some place other than the dust grain where the argon 40 is now found, the problem of an impossibly high age is averted.

Cosmic rays have also been bombarding the moon's surface, and several of the investigators have been seeking and analyzing the tracks they have left in the thin upper layer of the solid lunar material. A group led by Dr. R. L. Fleischer of the General Electric Research Laboratory in Schenectady, N.Y., reported identifying tracks created by the nuclei of iron atoms, probably from the sun, with energies lower than ever before observed. □



Fleischer

Cosmic ray tracks revealed by etching a sample of Apollo 11's lunar material.