ARGON SYSTEMATICS IN LUNAR FINES, D. Heymann* and T. Kirsten**

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Argon shows the greatest variation in isotopic composition among trapped inert gases in lunar fines. Measurements of argon in bulk grain-size fractions (1-11) have shown that Ar-40 and Ar-36 are always correlated by:

\[ \text{Ar}^{40} = K_1 \text{Ar}^{36} + K_2 \]

where \( K_1 \) and \( K_2 \) are parameters which vary from fines to fines. \( K_2 \) can be approximated with the potassium content of the fines (8). For Luna-20 fines \( K_1 = 1.41 \), \( K_2 = 0.49 \text{ cm}^2 \text{ STP/g} \) (11).

Two theories have been advanced to account for the presence of "excess" Ar-40 and the variation of \( K_1 \):

I) Ar-40, produced by K-40 decay in the Moon leaks into the atmosphere, where it is ionized, accelerated by the interplanetary electric field, and is, in part, retrapped in the top of the regolith. (2,12).

II) The particles now in the regolith were once coated with a potassium-bearing film. Part of the Ar-40 produced in this film became trapped in the particles, potassium was later removed by volatilization (13).

A number of objections have been raised against both theories. In this paper we will discuss these objections.

An objection against the first theory is that the thermal release patterns of Ar from lunar fines (13) do not confirm that atmospheric Ar-40 has been implanted with much smaller kinetic energy (\( \sim 1 \text{keV} \)) than solar-wind Ar-36 (\( \sim 30 \text{keV} \)).

However, recent studies of artificially implanted ions in lunar as well as terrestrial glasses (14) suggest that little of the trapped gases are contained in the strongly radiation-damaged outer skin of fines particles (500 \( \AA \) thick), but in energy traps in the less damaged, deeper regions. Phakey et al (15) have recently confirmed the existence of such traps (bubbles of about 80 \( \AA \) in diameter, but there are probably also smaller traps than these). If both Ar-36 and Ar-40 are now
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contained in such traps, then these gases should show nearly identical thermal release patterns.

An objection to the second theory is that the potassium from the films must have been volatilized at some time in the past—without quantitative Ar-40 loss—and must have been removed from the regolith, where it is not now present.

The variation in $K_1$ has been tentatively explained (8) by the assumption that the concentration of neutral Ar-40 in the lunar atmosphere varied in time. The observations of Heymann and Yaniv (8) and of Kirsten et al (16) suggest that the concentration has fluctuated up and down by more than a factor of 10 on time scales of $10^2$-$10^4$ years, but that, superimposed on these fluctuations there has been a more gradual decrease of the average concentration on time-scales of $10^6$ years.

The first authors have suggested that the variations in $K_1$ represent, albeit imperfectly, a record of the early lunar atmosphere, at a time when appreciable surface activity allowed considerable outgassing of the lunar interior (about 3-4 aeons ago). For this record to have been preserved, several conditions must be fulfilled. The erosion rate of particles less than 1 mm must be small, particularly during exposure to solar wind. Sputtering rates are now estimated as $0.02 \text{ g/year}$ (17), sufficiently small for the preservation of an ancient solar-wind record. If, however, erosion rates of rocks (3-10 $\text{ g/year}$) are prevailing (18), then any early solar-wind record is destroyed. However, the small, gas-rich regolith particles are probably destroyed rather than abraded by micrometeorite impacts. Hence, it is conceivable that the record of early solar-wind implantation (and of early atmospheric Ar-40) has been preserved by the surviving particles, and has not been wholly masked by solar wind implanted into more recently formed surfaces.

References

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