THE LUNAR CATACLYSM: ENERGY INFLUX INFERRED FROM ARGON AGE DATA.
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Of the lunar highland samples so far dated, 80 to 90 percent yield well defined $^4$He-$^3$He ages in the interval 3.9 to 4.0 Ga (1). The absence in these samples of radiogenic argon from their earlier existence in the lunar crust implies that they have typically been subjected to temperatures in excess of 500°C during and following the impact events which produced them (2). The minimum energy influx implied by these observations can be easily calculated and used to place constraints on mass influx 4.0 Ga ago regardless of whether the ages were reset by basin or crater impacts.

If one makes the reasonable assumption that the highland rocks have sampled (at least) the top 5 km of the lunar crust the energy influx, implied by the observation that this material was heated to 500°C or greater, is $6 \times 10^{12} \text{J/m}^2$. (It is perhaps worth noting that this corresponds to a mean energy influx between 3.9 and 4.0 Ga of the order of $2 \times 10^{-3} \text{W/m}^2$, i.e. around 4 per cent of the internal heat flow at that time). If the figure of $6 \times 10^{12} \text{J/m}^2$ is applicable to the whole of the lunar surface the total energy influx between 3.9 and 4.0 Ga ago is $\geq 2 \times 10^{26} \text{J}$ while for an area of $2.10^{12} \text{m}^2$ (comparable to the area of the Imbrium ejecta blanket) the minimum influx is $10^{25} \text{J}$. On the assumption of an impact velocity of 10 km sec$^{-1}$ the corresponding mass influxes are: $1.2 \times 10^5 \text{Kg/m}^2$ (equivalent to a 40 m. deep surface layer) $4 \times 10^{18} \text{Kg}$ and $2 \times 10^{17} \text{Kg}$.

These figures are lower limits to the actual energy and mass influx since they ignore multiple reheating and the (large?) fraction of energy involved in heating ejecta to lower temperatures. Nevertheless as lower limits they compare favourably with mass influxes calculated independently. Wetherill (3), for example, estimates a mass of $\sim 10^{18} \text{Kg}$ for the Imbrium planetesimal, an integral mass of $\sim 10^{17} \text{Kg}$ for the Fra Mauro and Cayley Plains cratering and only $3 \times 10^{16} \text{Kg}$ for the post mare cratering influx.

References:  