

## The late heavy bombardment of the Moon – how did it affect Earth and Mars?

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It has generally been assumed that the late heavy bombardment recorded on the Moon (Wasserburg *et al.*, 1977) rendered Earth uninhabitable until about 3.8 Ga, and severely affected living conditions for some time into the early Archaean. In contrast, the record from the earliest known metasedimentary rocks, extending back in time beyond 3.86 Ga show sequences of banded ironstones without the extensive mechanical disturbances that might be expected from planetary scale impacts. These rocks, and others like them which are slightly younger, also contain ubiquitous chemofossils with carbon isotopic composition suggestive of biochemically advanced microbial life forms (Mojzsis *et al.*, 1996). These conflicting observations together with new data obtained from the studies of the martian meteorites require a re-evaluation of the events in Earth-Moon space in this critical time interval.

Two possibilities exist. The bombardment, if assumed to have been caused by invading objects from outer space, could have been sufficiently episodic so that the effects have been missed in the discontinuous sequences investigated from the early Archaean. Life could in each of the occult major impact events have been extinguished only to arise again in the intervening quiescent time intervals of a few ten or hundred million years. Or it could have found a niche for survival in the deep ocean or crust, and spread again from there between each pair of major assaults (Sleep *et al.*, 1989).

The other possibility, supported by the lack of observable effects on Earth and Mars, is that the late lunar bombardment was not a solar system-wide process, but was largely limited to the lunar orbit. If the Moon formed from material ejected at impact between Earth and another planet, complete accretion of this material could have been delayed inside the Roche limit and by metastable storage in the Lagrangian points of the Moon's orbit, and the

impacting bodies could have been such delayed residual material from the formation of the Moon.

If the Moon was captured from solar orbit (Gerstenkorn, 1955), the late impactors could have been a set of appropriately small original satellites of Earth, swept up as the Moon, receded from Earth in its present prograde orbit (Alfvén and Arrhenius, 1972).

In any of these cases the impact velocities, because of the similarity in orbital elements could have been sufficiently low to retain the ejecta below escape velocity, and with escaping material, unless perturbed, returning to the orbital points of ejection, minimizing capture by Earth.

Contributing to the concept of the late lunar bombardment as a parochial lunar event (Mojzsis, 1998) is the observation that the Martian surface, if represented by the meteorite ALH 84001, has not been remelted since the crystallization age of 4.5 Ga.

All of the processes discussed above are highly speculative and each one suffers from dynamic difficulties. However, their main features can be experimentally tested. If the objects bombarding the Moon were derived from outer space or from the asteroid belt, the impact debris on the Moon as well as any captured by the Earth should be recognizable from its characteristic transition metal signature; initial results of a search for platinum group elements in the oldest Archaean metasediments are reported by Mojzsis (1998); a corresponding search of the lunar impact material is planned.

### References

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