Planetary atmospheres are probably the small difference between large sources and large sinks.

Planetary atmospheres are probably the small difference between large sources and large sinks.

Zahnle Kevin J.[1]
Kevin J. Zahnle[1]

[1] NASA Ames Research Center
[1] NASA Ames Research Center

Atmospheres are found enveloping those planets and satellites best able to hold them. The obvious inference is that volatile escape must have played nearly as great a role as volatile supply. A consequence of this view is that volatile supplies were probably much greater than the atmospheres that remain. Both sources and sinks must be considered.

The likeliest sources are associated with the main events of planetary accretion itself, such as volatile-rich planetesimals, or direct gravitational capture of nebular gases. Late asteroidal or cometary volatile-rich veneers present quantitative difficulties. Comets in particular are inadequate, because the associated mass of stray comets that would have been scattered to the Oort Cloud or beyond is excessive. This difficulty applies to Uranus-Neptune planetesimals as well as to a putative massive early Kuiper Belt. Another potential problem with comets is that the D/H ratio in the three comets for which this has been measured is about twice that of Earth's oceans. Objects falling from a much augmented ancient asteroid belt are an option, but timing is an issue: can the depopulation of the asteroid belt be delayed long enough that it makes sense to talk of asteroids as a late veneer? Early accretion of asteroids-as objects scattered into the maw of infant Earth-makes more sense. One way to do this is to mix into proto-Earths diet a few water-rich protoplanets from what is now the asteroid belt. Another possibility would be scattered planetesimals associated with the accretion of Jupiter, for two reasons: (i) before there was Jupiter, there was no object in the solar system capable of expelling comets efficiently; (ii) the cross-section of the inner solar system to stray objects was greater when there were many planetesimals.

This talk will emphasize the sinks. The likeliest sinks are volatile escape caused by impacts between planetesimals, and thermal escape caused by some combination of inadequate surface gravity, low mean molecular weight, and high levels of insolation. Another possible mechanism is the stripping of an atmosphere by a powerful solar wind (or magnetospheric wind in the case of the satellites of giant planets). Impact erosion can affect all volatiles including geochemical volatiles such as rubidium, although obviously it will affect atmospheres more than oceans, and oceans more the silicates. The other processes affect only atmospheres and oceans. Specific examples of atmospheric escape that may be addressed include (1) the escape of water from Venus; (2) the peculiar fact that xenon, the heaviest gas in Earth's atmosphere, preserves in its isotopes some of the strongest evidence that massive atmospheric escape has taken place from Earth; (3) the thinness of the martian atmosphere; and (4) the abundance of volatiles on satellites in the outer solar system.