TERMINAL CATACLYSM EPISTEMOLOGY:
A CATACLYSM THAT NEVER HAPPENED?
William K. Hartmann, Planetary Science Institute, 1700 Fort
Lowell Rd., Suite 106, Tucson AZ 85719 USA.
hartmann@psi.edu

The "terminal cataclysm" or "late heavy bombardment,"
LHB) concept of the last 40 years exhibits curious epistemology,
with changing definitions and inconsistent evidence.

Pre-Apollo evidence indicate an impact rate prior to ~3.5 Ga
ago averaging ≥~150x the post-mare rate [1]. In 1973-4, Tera et
al. [2, 3] introduced the term "terminal cataclysm" (TC) for wide-
spread metamorphism ~3.9 Ga ago --- caused either by the Im-
brium impact [3, p.15], or by formation of many basins in < 200
Ma [3, p.18]. In 1990, Ryder [4] reported a strong spike in Apol-
lo impact melt ages at ~3.85-4.0 Ga ago, and Moon-wide TC
bombardment at that time. He asserted what I have called “Ry-
der’s rule:" lack of earlier impact melts equates with lack of ear-
lier cratering. His work was widely adopted as proof of TC.

Three inconsistencies soon appeared. (1) Starting in 2000,
Cohen et al. [5] found no 3.9 Ga spike in KREEP-poor (non-
Imbrium?) lunar meteorite impact melt clasts. Still, they "sup-
port(ed)...lunar cataclysm," citing Ryder’s principle. (2) The
Nice model predicted sudden scattering of objects from the outer
to the inner Solar System [6], with a spike plausibly at ~3.9 Ga;
yet asteroidal meteorite impact melt clasts show no sharp spike at
~3.9 Ga. (3) In recent years, reports of pre-4.0 impact melts have
increased among upland breccia clasts, violating Ryder’s rule.

Dynamicists then re-introduced earlier ideas of "sawteeth"
spikes before 4.0, and gradual declines after 3.8, thus “melting
down” the cataclysmic spike into a mere bulge. In 2014 Marchi et
al. [7] modeled a declining impact flux, 4.4 to 3.5 Ga, with no
spike or bulge at 3.9 Ga. At the 2015 Houston conference on Ear-
ly Bombardment, several speakers excluded a 3.9 impact-spike
“TC.” Others supported the asteroidal bulge as showing “LHB”
though only the decline after 3.9 is visible in lunar data. The 3.9
“TC” appears to be collapsing; we should be concerned that it is
still being utilized in models for the formation of life on Earth.

A high, rather than low, pre-4.0 flux [1] can explain the data
[8, 9]. In this quantitative model, 3.9-4.0 Ga marks the transition
to probable survival of early impact melts. Pre-4.1 lunar impact
melt lenses in the upper kilometers were pulverized into dust and
upland megaregolith breccia clasts, recently being dated. Most
asteroidal impact melts from >4.1 were ejected into heliocentric
orbits from violent collisions, and removed by YORP forces ---
others were buried during reassembly after catastrophic fragmen-
tations. Deep-seated 4.4-era igneous “genesis” rocks, however,
are constantly replaced as ejecta from 10^2-km lunar and asteroidal
craters, and by recent asteroidal fragmentation events.