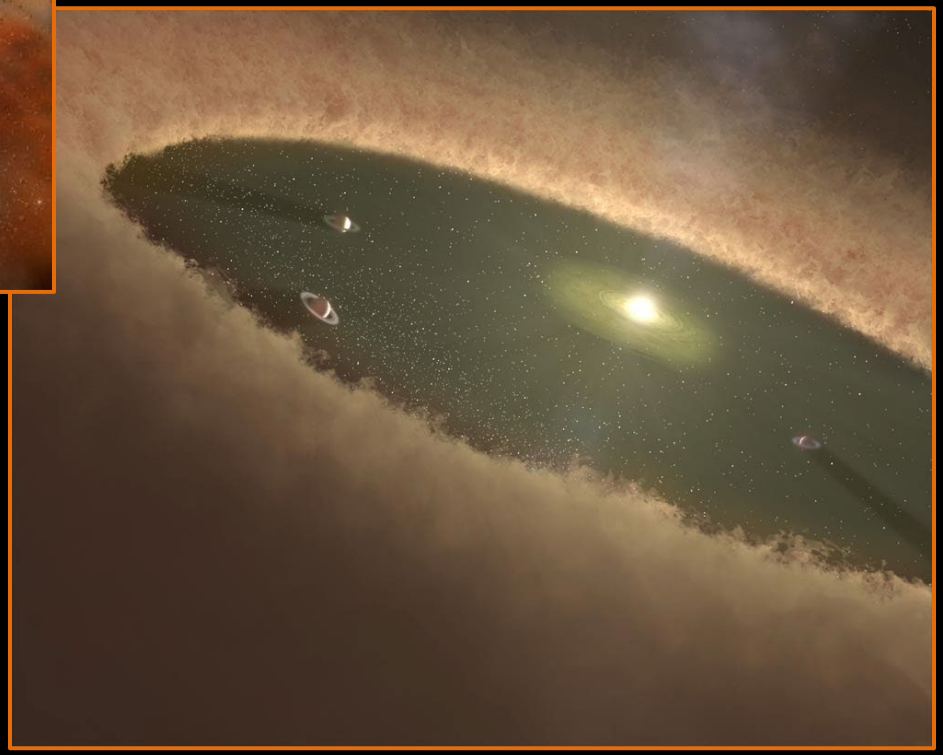
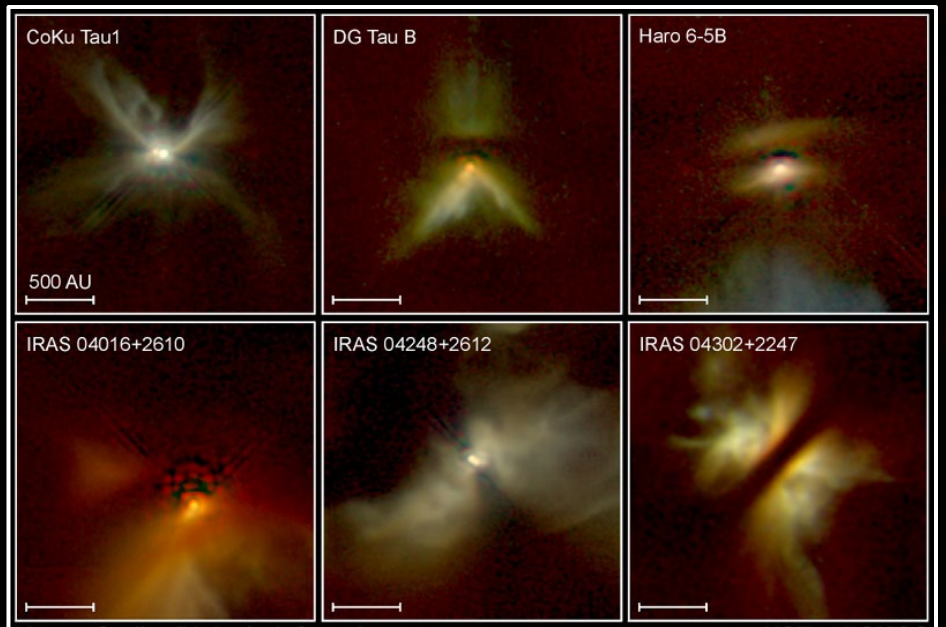
Protoplanetary disks



Edge-On Protoplanetary Disk
Orion Nebula
HST · WFPC2
PRC95-45c · ST ScI OPO · November 20, 1995
M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA



Young Stellar Disks in Infrared
HST • NICMOS
PRC99-05a • STScI OPO
D. Padgett (IPAC/Caltech), W. Brandner (IPAC), K. Stapelfeldt (JPL) and NASA

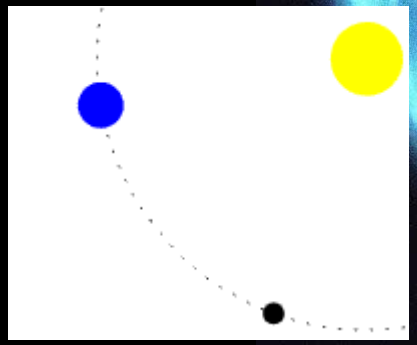
HL Tauri circumstellar disk

ESO/ALMA

Dist: ~450 Lt-yrs
Radius: ~80AU

Origin of the Moon

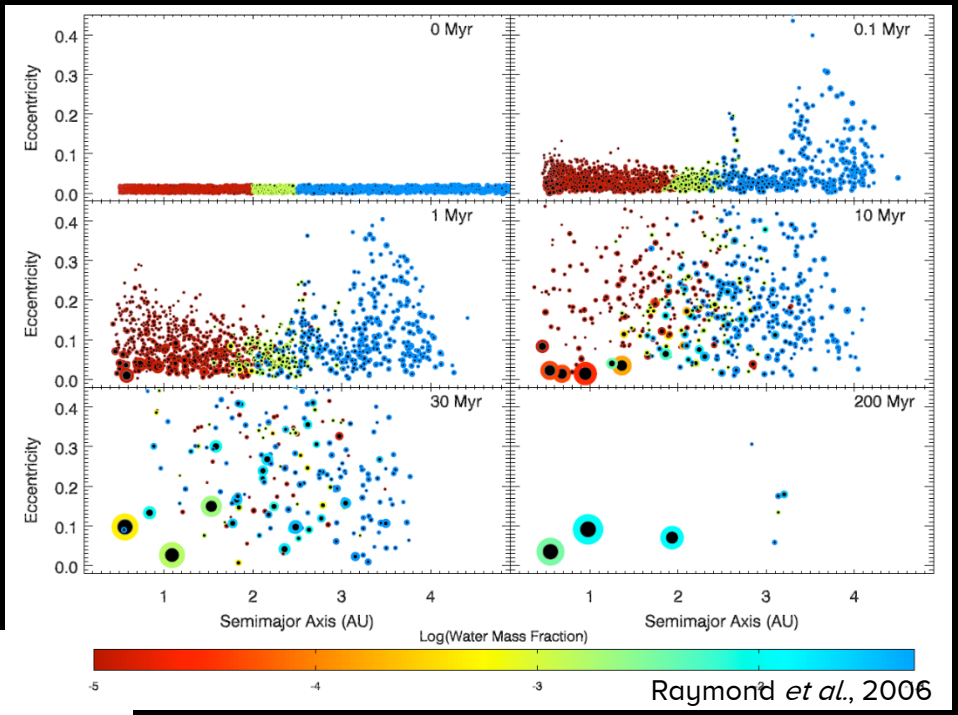
Theia is ‘Titaness’ in Greek mythology, and the mother of Selene, the goddess of the Moon.



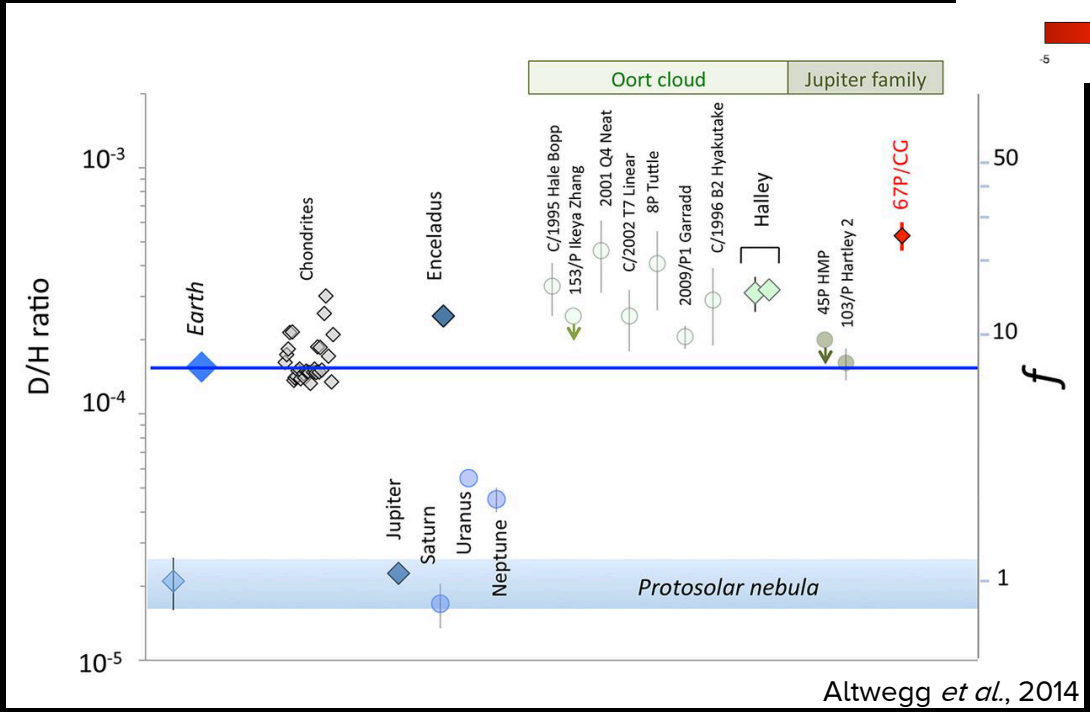
Animation of the ‘Big Splash’ as Theia impacts the young Earth. (Wikimedia)

Origin of the Ocean

Earth's extensive reservoir of water was likely delivered in the late stages of planetary formation by impacts with bodies originating from beyond the 'ice line' in the Solar System, like TNOs, comets and protoplanetary embryos.



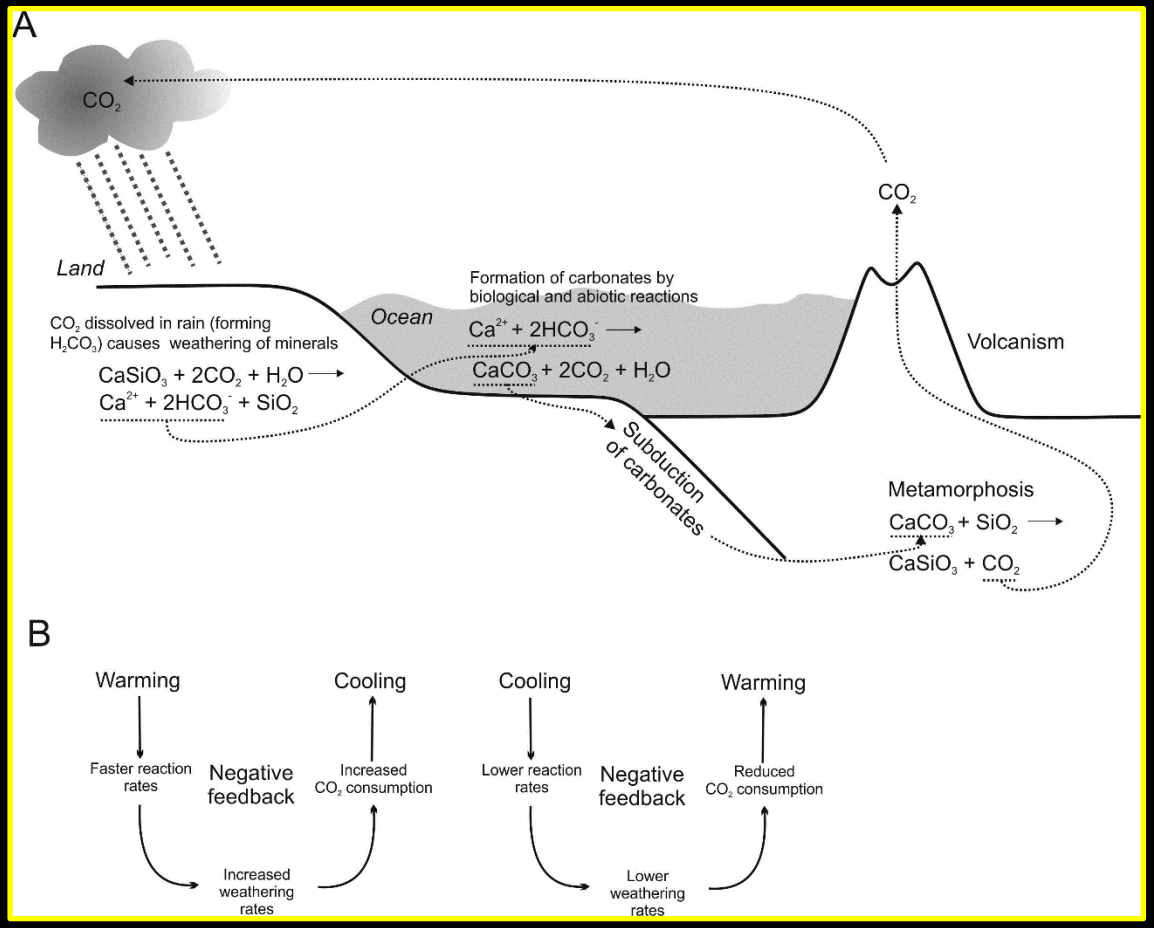
Raymond *et al.*, 2006



Altwegg *et al.*, 2014

Both dynamical modelling simulations (above) and the D/H ratio (deuterium/hydrogen) ratio of Earth's water (left) support this hypothesis, falling closer to that of outer Solar System objects and comets than protosolar values.

The Carbonate-Silicate Cycle



Cockell *et al.* (2016) - *Astrobiology*

~100k years

$CO_{2(g)}$ in air

↓

$CO_{2(aq)}$ in rainwater

↓

H_2CO_3 dissolves silicates

↓

Ca, HCO_3^- (also Mg, Mn, Al, Si etc.) washed to sea

↓

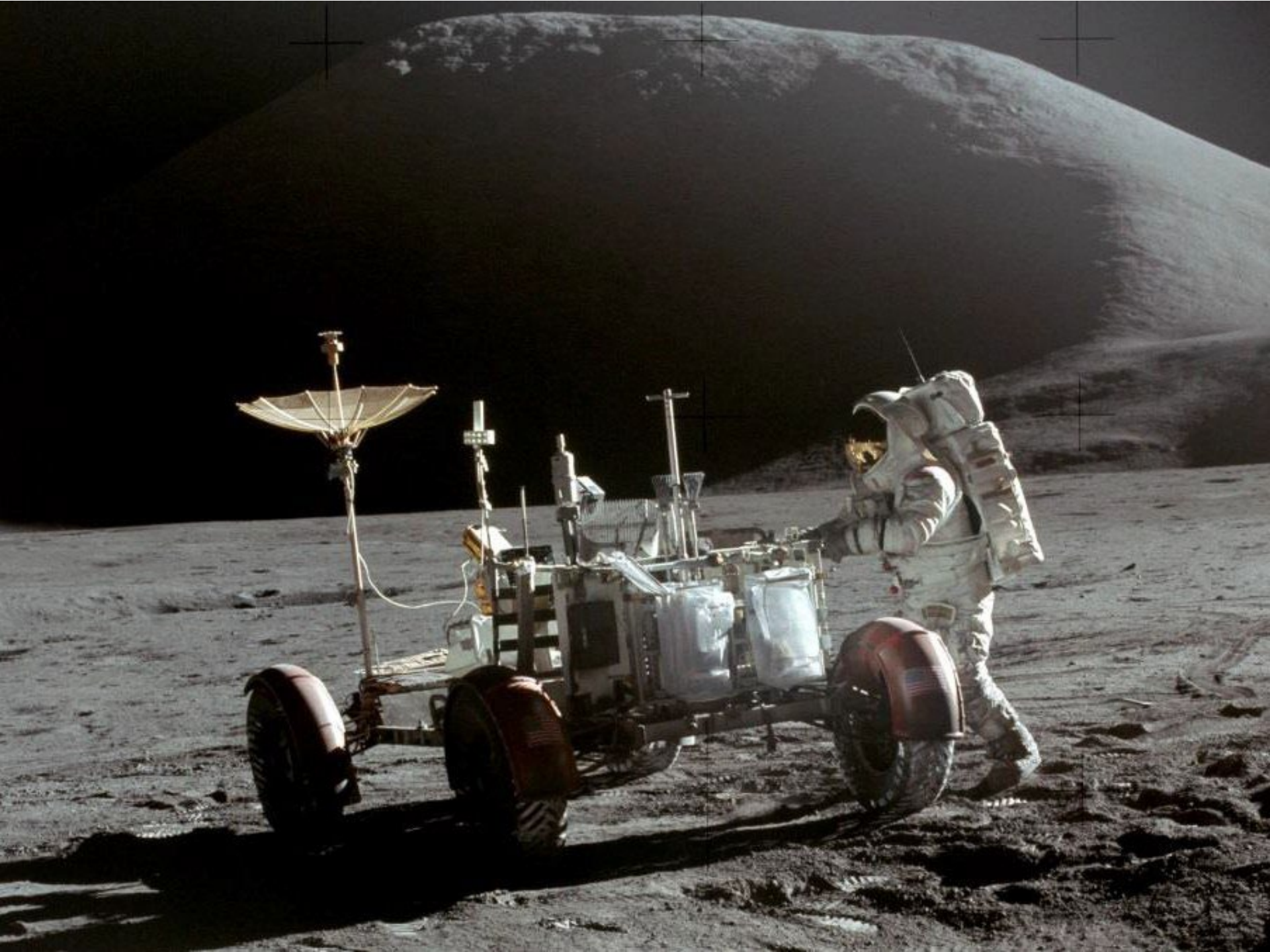
Used by organisms to build shells of $CaCO_3$, or natural precipitation at high CO_2.
Small % sinks to bottom of ocean.

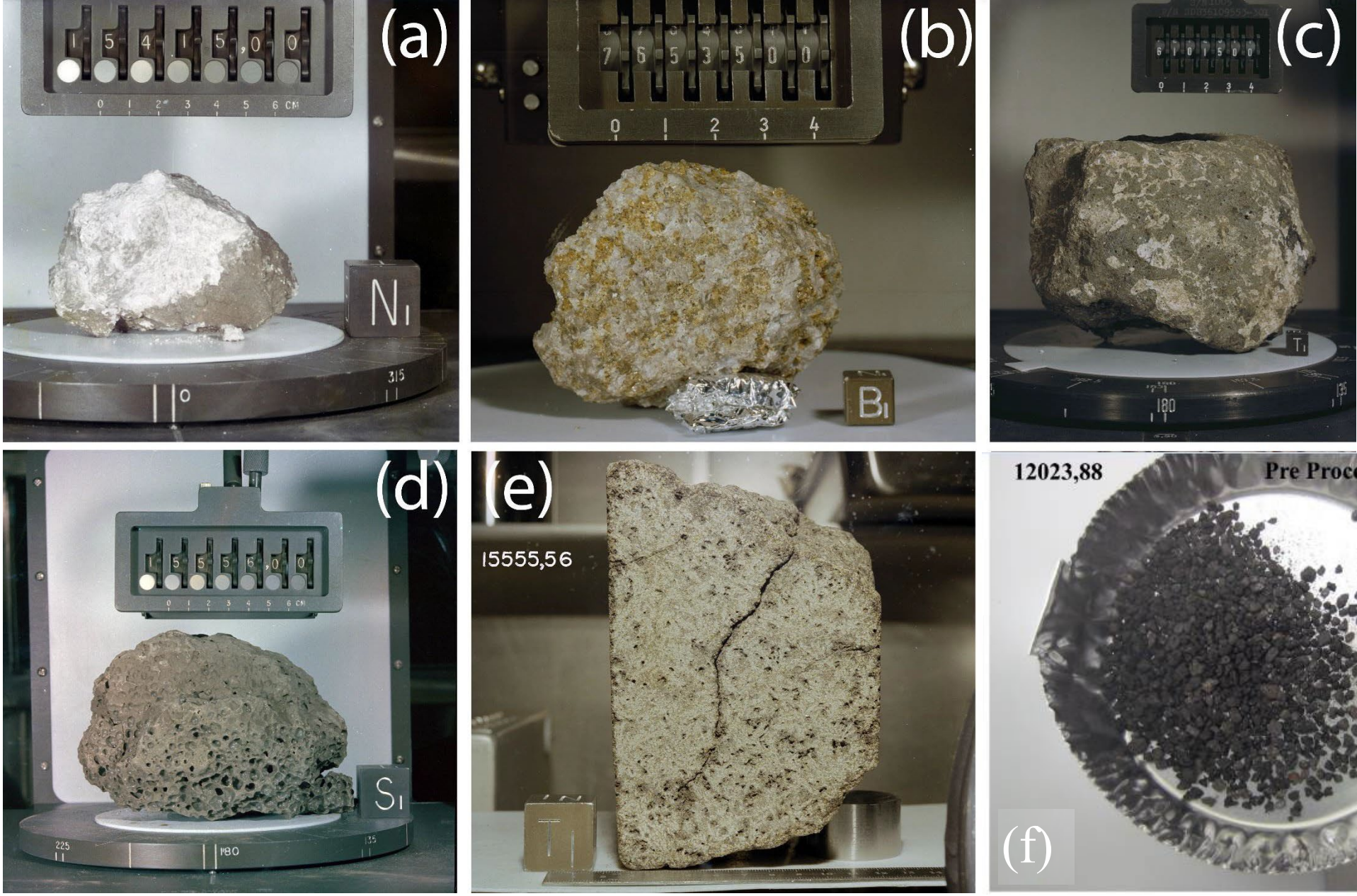
↓

Subducted

↓

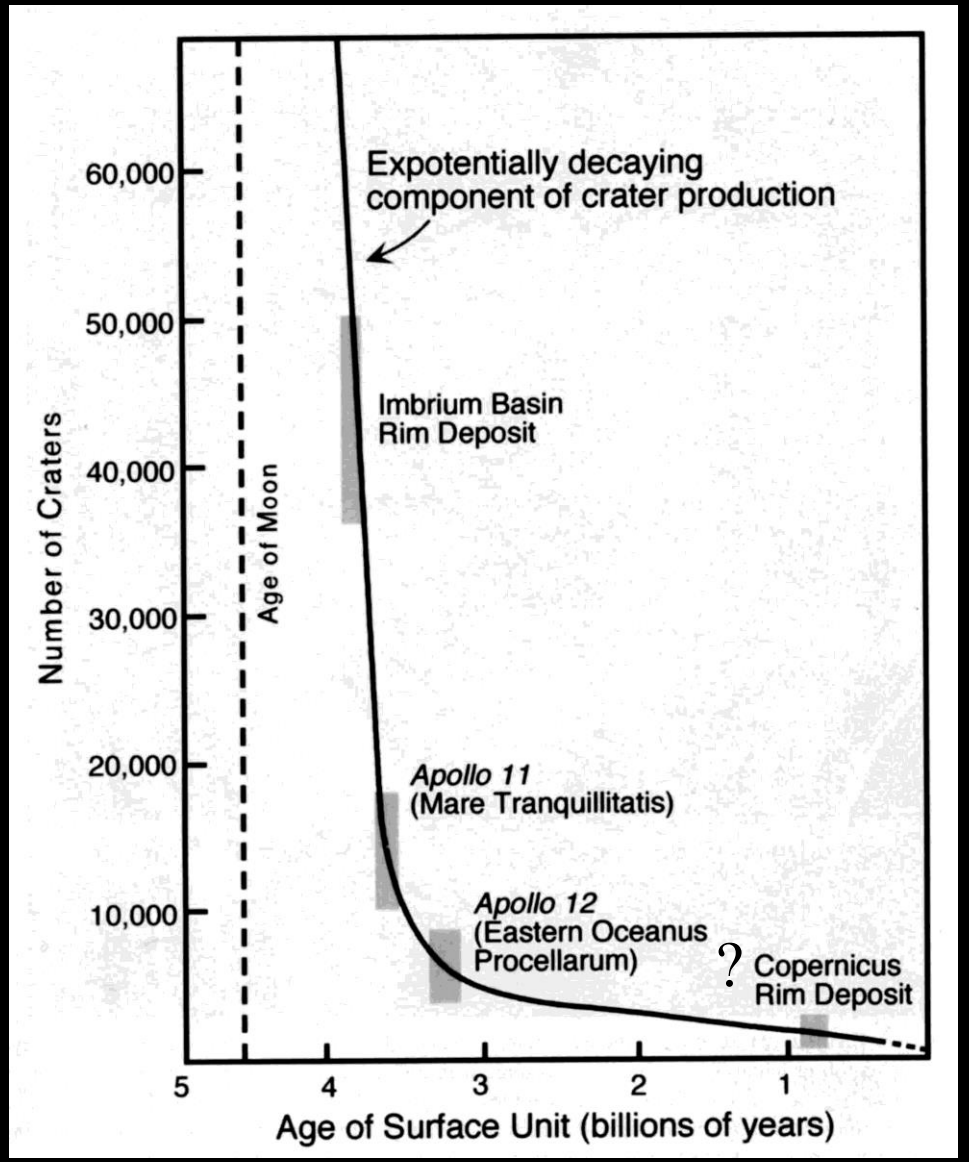
Outgassed by volcanoes





Apollo samples

The Late Heavy Bombardment



The Lunar Cataclysm Hypothesis