Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35167

Biological Drivers of Planetary Transformation

DAVID WATTERS

Astraloft, LLC

Hypothetical Earth-analog exoplanets provide comparative insight into conditions suitable for the development of advanced life on Earth, especially conditions supporting sustained biotic processes in the Archaean that contributed to eventual atmospheric oxygenation. Advanced life can thrive when planetary cooldown time that achieves a modest mantle potential temperature matches solar-forced burndown of an initially-high pCO_2 protective atmosphere to a concentration consistent with human habitability (<400 ppm) midway through the stellar lifecycle. This requirement pairs small rocky planets with fast burning F-type stars, and super-Earths with cooler K-type dwarfs. Magnetic-field collapse and atmospheric retention limit the development timeline on small planets. Tidal locking in close habitable-zone orbits and a high gravitational acceleration constrain habitability on large planets. Earth-sized planets (M_p = 0.85-2.0 $M_\oplus$) orbiting G-type stars provide the best conditions for development of advanced life [1].

Counter to this trend, the time required for atmospheric oxygenation, which is associated with mantle transport time, observes an inverse sublinear relationship with planet mass [2]. Accordingly, small planets need more time to accomplish their Great Oxygenation Event than super-Earths. To the extent biological processes assist in this transformation, smaller planets become candidates for advanced life. Alternatively, delayed Archaean transformation [3] affects the timeline for human habitability, making advanced life more probable orbiting low-mass G-type stars (Fig. 1).

We use Bayesian inference to evaluate drivers of Archaean change, comparing environmental predictions associated with abiotic and biotic processes against atmospheric, oceanic, and geochemical evidence. The comparison includes surface temperature regulation, carbon source-sink balance, phosphorus availability, ocean surface oxidation, iron deposition, slab subduction, atmospheric methane concentration, and increasing mantle oxygen fugacity. Posterior probabilities favor a sustained, comprehensive role for microbial ecosystems that stir biogeochemical cycles and accelerate Earth's redox transformation, making advanced life possible on small rocky planets orbiting high-mass G-dwarfs. The low gravitational acceleration associated with these planets makes them ideal hosts for technologically-capable civilization.

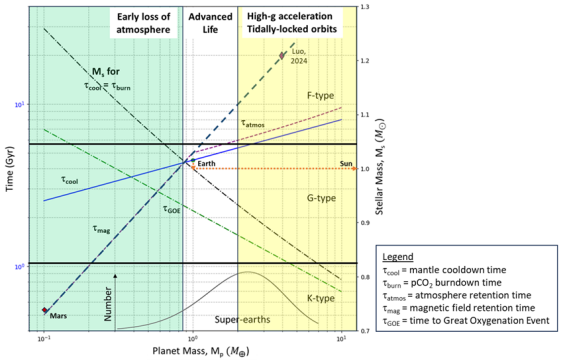

Figure 1. Development-time trendlines vs. planet mass, showing corresponding best-matched star.

1. Watters & Korzun (2025), Goldschmidt, https://doi.org/10.7185/gold2025.27272.
2. Valencia & O'Connell (2009), *EPS Letters*, 286(3-4), 492-505.
3. Horne & Goldblatt (2024), *Geochemistry, Geophysics, Geosystems*, 25, e2023GC011252.