Galactic chemical evolution models and the geophysical nature of cosmochemically Earth-like planets

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We assess the geophysical effects of different rock-forming element abundances (e.g. [Mg/Si]) on geodynamic regimes under the assumption that this is required for long-term habitability of a cosmochemically "Earth-like" planet. We use computational GCE codes to model galactic abundances of elements with time [ref.1] with several key improvements on stellar production of short- (^{26}Al, ^{60}Fe) and long-lived heat generating nuclides (^{40}K, ^{235,238}U, ^{232}Th). We address how temporal variations in initial radionuclide abundances yield different heat productions and relate this to how different mantle compositions cause different mantle viscosities and chemical states; specifically [2; O'Neill, *pers. comm.*]: (i) Earth's Primitive Mantle [Mg/Si] ratio is ~1.03; (ii) The dominant *upper mantle* (*UM*) phase is olivine that cannot accommodate Fe^{3+}; (iii) If Earth inherited a lower [Mg/Si] (e.g. 0.8), pyroxene would dominate. Pyroxene takes up Fe^{3+} into its structure and with substitutions maintains low activity of Fe^{3+} and a very low oxygen fugacity; (iv) Owing to (ii), Fe^{3+} in the Earth's *UM* goes into spinel that imposes a high oxygen fugacity (~FMQ) on gases in equilibrium with rock; hence, (v) Earth's *UM* degases CO-CO_2 rather than CH_4-CO. A plausible exoEarth with Mg/Si=1 would have a stiff lower mantle compared to one with Mg/Si=1.2 owing to the abundance of bridgmanite (strong) vs. ferropericlase (weak). It is evident that subtle changes in [Mg/Si] in different solar systems have the potential to either yield a convecting (pure olivine) interior with plate tectonics or a stiff, (pure pyroxene) mantle that is substantially hotter.

References: [1] Frank et al. (2014) *Icarus* **243**, 274-286. [2] Palme & O'Neill (2014) Treatise on Geochemistry 2nd ed. http://dx.doi.org/10.1016/B978-0-08-095975-7.00201-1.