**Introduction.** The processes and branch points of planetary evolution that produce the differences among our terrestrial planets are not well understood. In a variety of interconnected ways, though, the mass of the planet and its bulk composition, along with its proximity to its star, control its tectonics and geodynamics.

The surfaces of Mercury, Venus, and Mars are all far older than the Earth’s. Here I will present a timeline for early planetary evolution, pointing out potential turning points, and aspects that are thought to control tectonics and geodynamics.

**Snapshots from the evolution of a rocky planet.** Accretionary impacts likely create serial magma oceans on growing rocky planets. The magma ocean stage sets the initial interior and exterior volatile inventories of rocky planets, and the volatile inventory in turn affects all aspects of tectonics and climate.

Earth’s water comes from rocky material analogous to meteorites [1]. This source was likely the planetesimals that built the planets. How these volatiles are partitioned between interior and surface during planetary magma ocean solidification is a complex problem [2, 3].

The freezing of a magma ocean will leave some concentration of volatiles in the planetary interior. For a given bulk composition, the mass of the planet prescribes its internal pressure and thus the stable mineral phases of its mantle. Each mineral phase has its specific ability to accept hydroxyl or other incompatible elements or compounds, and interstitial liquids will trap a further volatile fraction.

The interior volatile inventory of a planet, in particular its water inventory, controls the mantle viscosity, and thus convective vigor and degree of coupling between the mantle and lithosphere. This interior inventory may be decoupled from surface conditions to some degree, however. A thick lithosphere can prevent significant volcanic degassing. A close proximity to the star can remove atmosphere. Thus, though Venus’ surface is drier than the Earth’s, its interior may be similarly volatile rich.

Calculations for the cooling and collapse rates for the young steam atmosphere vary from tens of thousands to tens of millions of years, depending upon the mass of the steam atmosphere and the model being employed [4-7]. If the atmosphere cools and collapses quickly this initial water is more likely to be retained; a puffed-up steam atmosphere can be stripped away by the high ultraviolet activity of a young star. Venus may have suffered such a fate, being closer to the Sun than the Earth is [7-9]. Mars may also have begun drier than larger planets because of stripping of the early atmosphere [10].

Following the final giant accretionary impact a planet cools. Though hot, if its mantle solidified fractionally then compositional density stratification will suppress thermal convection for some time [11, 12]. Without vigorous mantle convection, the top thermal boundary layer may have a chance to thicken enough to suppress or delay plate tectonics. Single-plate planets appear to dominate our solar system [13]. Plate tectonics, however, is a poorly understood process and the causes and conditions of its initiation is the topic of significant disagreement [14-18].

Rather than approaching plate tectonics from the point of view of mantle convection, the problem may be thought of as the balance between brittle fault development and annealing [19]. The maintenance of brittle faults is required to keep plates separate and able to move, and so both hotter mantles (as in young planets) and hotter surfaces (for example, Venus) will suppress plate tectonics [20]. Venus may well be too hot to allow Earth-like plate tectonics to persist [20], and may either resurface volcanically periodically [21], or gradually and continually [22]. Slow recycling, through dripping lithosphere, may be normal on one-plate planets. Such lithospheric dripping can produce both volcanism and volatile recycling [23].

**References:**