# Planetary Evolution and Habitability

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Planetary habitability is usually thought to require water on (or near) the surface, a magnetic field to protect life against cosmic radiation, and transport mechanisms for nutrients. A magnetic field also serves to protect an existing atmosphere against erosion by the solar wind and thus helps to stabilize the presence of water and habitability. Magnetic fields are generated in the cores of the terrestrial planets and thus habitability is linked to the evolution of the interior. Moreover, the interior is a potential source and sink for water and may interact with the surface and atmosphere reservoirs through volcanic activity and recycling. On the Earth, water is stabilized by complex interactions between the atmosphere, the biosphere, the oceans, the crust, and the deep interior. The most efficient known mechanism for recycling is plate tectonics. Plate tectonics is known to operate, at present, only on the Earth, although Mars may have had a phase of plate tectonics as may have Venus. Single-plate tectonics associated with stagnant lid convection can also transfer water from the interior but a simple recycling mechanism is lacking for this tectonic style. Stagnant lid convection will evolve to thicken the lid and increasingly frustrate volcanic activity and degassing. (This can keep the interior from running completely dry.) Plate tectonics also supports the generation of magnetic fields by effectively cooling the deep interior. (In addition, plate tectonics rejuvenates nutrients on the surface and generates granitic cratons.) For Mars and Venus it is likely that a present-day magnetic field would require plate tectonics to operate. An early field is possible even with stagnant lid convection but the dynamo will only operate less than about a billion years. This dynamo would have been driven by thermal buoyancy and require that the core was sufficiently superheated with respect to the mantle after core formation. The dynamo would have ceased to operate as the core cooled depending on the vigor of mantle convection. A question is then whether or not plate tectonics existed on Mars and Venus and if yes why plate tectonics ceased to operate. Or, more generally, why do planets have plate tectonics and others do not? Convection model calculations suggest relations to the yield strength of the mantle and the effect of water on the latter. Other models suggest that the existence of an asthenosphere (a low viscosity zone underneath the lithosphere) may be decisive. The presence of water will lower the solidus of mantle rock and help to form an asthenosphere. Thus, there appear to be links between plate tectonics and (near) surface water, plate tectonics and magnetic fields, magnetic fields and habitability, and habitability and water. Is plate tectonics even a potential biosignature?