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# Geophysical Limitations on the Habitable Zone: Volcanism and Plate Tectonics

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Planets are typically classified as potentially life-bearing planets (i.e. habitable planets) if they are rocky planets and if a liquid (e.g. water) could exist at the surface. The latter depends on several factors, like for example the amount of available solar energy, greenhouse effects in the atmosphere and an efficient $CO_2$-cycle.

However, the definition of the habitable zone should be updated to include possible geophysical constraints, that could potentially influence the $CO_2$-cycle. Planets like Mars without plate tectonics and no or only limited volcanic events can only be considered to be habitable at the inner boundary of the habitable zone, since the greenhouse effect needed to ensure liquid surface water farther away from the sun is strongly reduced. We investigate if the planet mass as well as the interior structure can set constraints on the occurrence of plate tectonics and outgassing, and therefore affect the habitable zone, using both parameterized evolution models [1] and mantle convection simulations [1,2].

We find that plate tectonics, if it occurs, always leads to sufficient volcanic outgassing and therefore greenhouse effect needed for the outer boundary of the habitable zone (several tens of bar $CO_2$), see also [3]. One-plate planets, however, may suffer strong volcanic limitations.

The existence of a dense-enough $CO_2$ atmosphere allowing for the carbon-silicate cycle and release of carbon at the outer boundary of the habitable zone may be strongly limited for planets: 1) without plate tectonics, 2) with a large planet mass, and/or 3) a high iron content.

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**References**

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