## Venus: from a Terrestrial Ocean to a Possible Habitat in the Lower Atmosphere

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In its first 500 million years Venus started out with environmental conditions very similar to Earth, including the presence of an early ocean on its planetary surface [1]. However, it is unclear how long the ocean remained stable on the Venusian surface. Some estimates indicate that liquid water was present on the Venusian surface for a billion years or longer [2]. If so and taking into account the dynamic endogen-driven activity on Venus, the origin of life on Earth's twin planet or its proliferation through panspermia (e.g. through transport from Earth) seems reasonable. Once life was present on Venus, it would have become established in the ocean or oceans, and spread into environmental niches. Since the ocean on Venus was probably hot for a considerable period of time [1, 3], thermophilic chemotrophs and phototrophs, but possibly also heterotrophic microorganisms could have become established on Venus.

As the Sun increased in brightness and Venus increased in temperature through its thickening greenhouse gas atmosphere [2], life could have coped with these changes through directional selection. There are several examples of microbial life on Earth, which thrive at high temperatures [e.g. 4, 5, 6]. The dramatic shift in climate could have happened fast, in which case the environmental change would have probably been catastrophic to life resulting in the extinction of life on the planet. Or, microbial life could have retreated to one potential habitat still available: the lower cloud layer. The possibility of life in the lower Venusian atmosphere has been discussed by various authors [2, 3, 7, 8, 9, 10]. Several parameters that are favorable to the possible habitability of the cloud layer today can be pointed out:

**1.** The clouds of Venus are much larger, more continuous, and stable than the clouds on Earth.
- The atmosphere is in chemical disequilibrium, with $H_2$ and $O_2$, and $H_2S$ and $SO_2$ coexisting.
- The lower cloud layer contains non-spherical particles comparable in size to microbes on Earth.
- Conditions in the clouds at 50 km in altitude are relatively benign, with temperatures of 25 to 75°C, pressure of 100 kPa, and a pH of about 0.
- The super-rotation of the atmosphere enhances the potential for photosynthetic reactions.
- COS is present in the atmosphere, which on Earth is a strong indicator of biological activity.
- CO is less abundant than expected under Venusian atmospheric conditions, and could be oxidized as a reactant in plausible metabolic pathways.
- The biologically critical elements of carbon, phosphorus, and nitrogen are present.
- While water is scarce on Venus, water vapor concentrations reach several hundred ppm in the lower cloud layer.

However, any putative organism would have to deal with low pH, desiccation and high UV irradiation. At this time, there is no known microorganism on Earth, which can grow under these combined conditions. Nevertheless, putative Venusian microbes could have evolved the needed adaptations if the climate change occurred slowly [10]. These combined stresses do not often occur on Earth; thus, evolutionary pressure is not as intense to evolve this kind of adaptation. But on Venus it would be and so there is a chance that life could still be present at Venus today.

**References**

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**Short Summary**

Conditions on early Venus were very similar at a time when life first arose on Earth. Thus, life could have evolved on Venus independently or brought in from Earth by asteroids. As temperatures on Venus increased, life might have found a habitable niche in the lower Venusian atmosphere.