Metabolic, physiological and geographical borders for Terrestrial Life

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Until a rather recent period, life was only known in the most superficial regions of Earth. Indeed, organisms had been discovered in the deepest trenches of the oceans, but remained apparently limited to the upper layers of sediments. The discovery of deep-sea hydrothermal vents in 1977 suddenly revealed that a large portion of Earth was still unexplored and that novel living communities existed. These extreme environments fascinated the biologists and particularly the microbiologists who explored the frontiers of life.

Thirty years ago, the deep-sea was known as a low density biotope due to coldness, darkness and famine-like conditions. The discovery of deep-sea hydrothermal vents in the Eastern Pacific in 1977 and the associated black smokers in 1979 considerably changed our views about life on Earth. For the first time, an ecosystem almost independent (at least for tens of years) of solar nergy was discovered. Besides the spectacular and unexpected communities of invertebrates based on symbiotic associations with chemo-litho-autotrophic bacteria, prokaryotic communities associated with high temperature black smokers fascinated microbiologists of extreme environments.

Within mineral structures where temperature gradients may fluctuate from ambient seawater temperatures (2˚C) up to 350˚C, thermophilic (optimal growth above 60˚C) and hyperthermophilic (optimal growth above 80˚C) microorganisms thrived under very severe conditions due to elevated hydrostatic pressure, toxic compounds or strong ionizing radiations. These organisms belong to both domains of Bacteria and Archaea and live aerobically but mostly anaerobically, using a variety of inorganic and organic carbon sources, and a variety of electron donnors and acceptors as well.

The most thermophilic organism known on Earth was isolated from a mid-Atlantic-Ridge hydrotermal vent: *Pyrolobus fumarii* grows optimally at 110˚c and its upper temperature limit for life is 113˚C. Such an organism survived to autoclaving conditions currently used for sterilization procedures. Many other hyperthermophilic organisms were isolated and described, including fermenters, sulphate and sulphur reducers, hydrogen oxidizers, nitrate reducers, methanogens, etc. Although most of anaerobes are killed when exposed to oxygen, several deep-sea hyperthermophiles appeared to survive to both oxygen and starvation exposures, indicating that they probably can colonize rather distant environments

Because of elevated hydrostatic pressure that exists at deep-sea vents, hydrothermal fluids remain liquid at temperatures above 100˚C (boiling water temperature under atmospheric pressure). If strictly barophilic thermophiles or hyperthermophiles have not been reported yet (the deepest vents known are 3500 m in depth), barophilic Bacteria and Archaea have been reported that grow much more faster when exposed to in situ (pressurized) conditions. Morover, they grow preferentially at pressures above those existing at captures depth, that may indicate that their natural habitat is situated below the sea floor.

Indeed, besides these physio-chemical limits, frontiers of life also moved geographically with the development of drilling technologies and the discovery of active microorganisms in deep aquifers, oil reservoirs, deep rocks and deep marine sediments. The realty of a huge and diversified deep biosphere was more and more demonstrated.

However, despite numerous examples of deep environments, many questions still remain. One cannot avoid that in some cases, contamination of samples might have occurred and gave false postive results. This is particularly the case when spore-forming organisms are detected and re-cultured from inclusions of several million year old. Another question is that of the real *in situ* activity of these communities and the origin of their carbon and energy sources and their electron acceptors.

Nevertheless, it is clear that during the last decades, borders for terrestrial Life have been considerably expended, and true limits are still unknown. Consequently, remote objects of the solar system where life could not be seriously imaginated several years ago, are now fascinating targets for life detection in the next future.