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This essay complements the article "Phoenix on Mars" / "Phoenix auf dem Mars"; see information at end of text

Planetary Research

Why Mars?

by Walter Goetz

The exploration of our neighbor planet offers a unique chance. It is similar to our own planet, but appears not to harbor life. Through comparative studies of both planets we may come to understand, how life could evolve on Earth.

Among all planets in the solar system Mars is the one that most closely resembles Earth. This statement refers to surface mineralogy, geology and meteorology and remains true despite substantial differences between both planets. The morphology of numerous erosion features and the presence of minerals precipitated from aqueous solution (such as clay minerals, sulfates, carbonates or iron oxides, some of these even water-containing) suggest that liquid water once existed on (or near) the surface of Mars and – though in small quantities – still may persist up to now. In general these observations are believed to indicate a denser atmosphere on early Mars.

However, what was this dense paleo-atmosphere made of? Carbon dioxide? Water vapor? Sulfur dioxide? And how did the early atmosphere evolve? Have there been large amounts of liquid water (rain, rivers, lakes, oceans) on the surface of Mars? Or was it more like an ongoing subsurface circulation of hydrothermal fluids (aqueous solutions) that reached the surface sporadically to form the observed erosion features and mineral deposits on short time scales?

Today we know that Mars and Earth followed very different paths of evolution. What they had in common was liquid water (at or below the surface) and widespread volcanism in the early part of their history. Apparently, both planets were "habitable", although the conditions for the evolution of life may not have been equally favorable on both planets.

However, primitive life likely did exist on Earth as early as about four billion years ago (Rosing 1999, Wilde 2001). Why not on Mars? And which role did our huge Moon play for the evolution of life on Earth? By stabilizing the obliquity of the Earth’s spin axis it may have damped climatic changes over geological time scales, as pointed out by the French astronomer Jacques Lascar (Nature, 1993). Mars with its tiny potato-shaped moons (smaller than 30 km) lacks this strong effect, hence resulting in reduced opportunities for life to evolve.

The Earth provides the proof: On a local scale matter *is* able to evolve to a state of higher order and to generate organized structures of high complexity including genotype. In order to understand this remarkable process we need to consider earth-like planets that have only reached some lower stage in their evolution.

Assuming that it once evolved on the surface of Mars, life should have been able to adapt to a changing environment. In fact, terrestrial life is extremely adaptable. Some terrestrial extremophiles are able to cope with very low or very high temperatures, others such as *Rubrobacter* or *Deinococcus radiodurans* thrive at high radiation levels in nuclear reactors. It is conceivable that potential present-day biotopes on Mars are inaccessible for ordinary landed missions. The bio-/geochemical markers that attest to potential early life may be faint and probably will require highly specific and possibly very sensitive experimental methods. But what should be "specifically" looked for? And in the case of Mars Sample Return (MSR) missions that currently gain priority in the long-term Mars Exploration Program (post 2020): How should these samples be collected and packaged such that potential bio-tracers will be preserved during return to Earth?

The surface of the Earth is dominated by comparatively young rocks that are of sedimentary or igneous origin and generally less than 0.5 billion years old. Mars is only marginally active, mainly through slow exogenic wind erosion rather than endogenic processes like volcanism or plate tectonics. Hence present-day Mars does not demonstrate those latter processes. Rather it shows the products of those processes that were active in the given early environment of the planet: Were low-temperature processes on the surface of Mars limited to inorganic chemistry in a wet reactive atmosphere or in aqueous solution? Or did they include primitive metabolism as long as environmental conditions were favorable? In that sense Mars is a window back in time, and thus potentially a window back to the origin of life.

Literature:

Laskar, J. et al.: Stabilization of the Earth's obliquity by the Moon. In: Nature; vol. 361, pp. 615 - 617, 18-Feb-1993. Online at http://www.nature.com/nature/journal/v361/n6413/abs/361615a0.html

Rosing, Minik T.: ^{13}C-Depleted Carbon Microparticles in >3700-Ma Sea-Floor Sedimentary Rocks from West Greenland. In: Science, vol. 283(5402), pp. 674 - 676, 29-Jan-1999. Online at http://www.sciencemag.org/cgi/content/abstract/283/5402/674?ck=nck

Wilde, Simon A. et al.: Evidence from detrital zircons for the existence of continental crust and oceans on the Earth 4.4 Gyr ago. In Nature, vol. 409, pp. 175 - 178, 11-Jan-2001. Online at http://www.nature.com/nature/journal/v409/n6817/full/409175A0.html.

Additional web link:

http://www.geology.wisc.edu/zircon/zircon_home.html
"Zircons are forever" – about the importance of zircons for geochronology (University of Wisconsin-Madison)

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