

A HUMAN SIGNATURE ON MARS AS A SYMBOL OF A FUTURE TERRAFORMING

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ABSTRACT

As stated by Robert Zubrin, two questions are leading humans towards the exploration of Mars: i) is or was there any life and ii) will there be life in a near future? A similar biochemistry between the Earth's and Martian life forms would imply a common origin attributable to stone-borne interplanetary transfers or to a seeding of our Solar system during its formation. Presence of Martian life or traces of its previous existence will have not only scientific consequences, but also cultural and social implications for humans, regarding their intellectual, philosophical or religious attitudes towards the origin of life on the Earth. The terraforming of Mars and, more generally, the spreading of Earth's life forms to other celestial bodies are questions of primordial importance that should be the focus of a public debate.

To provoke such a debate and to symbolize the crossroads at which our civilization now stands, we propose a mixed art-and-technology project. The symbol we propose is an open human hand transformed into an image composed of 391 pixels of four levels of grey, allowing the recognition of the hand without any consideration of age, gender or race. This newly created picture is translated into a nucleotide sequence, using the biochemistry of the genetic code common to terrestrial life forms, such that each level of grey is associated with one of the four DNA bases according to their complexity. Once synthesized, this non-functional, 391 nucleotides long, sequence is inserted into the chromosome of *Bacillus subtilis*, a spore-forming bacterium. One gram of spores of this engineered strain contains 10^{12} cells, and, therefore, an equal number of copies of the synthetic message. Since spores embedded in amber can remain alive for at least 30 million years, this human generated artifact would be almost eternal.

As a beginning of a universe-wide dispersion of terrestrial life forms, people will be soon on Mars, exploring and contaminating it. The "open hand" symbol will be that of the mankind starting the terraforming of Mars. It will be destined to highlight the responsibilities taken by humans in this adventure. It could be a label, denoting that the enterprise has been freely and widely debated by men, within the limits of their hopefully ever progressing consciousness of what this adventure may open up to humanity.

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INTRODUCTION

As stated by Robert Zubrin (Zubrin and Wagner, 1996), two questions are leading humans towards the exploration of Mars: is or was there any life and will there be life in a near future?

Regarding Martian life, the recent description of putative remnants of life in a Martian meteorite (McKay et al., 1996) is very much debated by the scientific community. As soon as released, this information was widely discussed in the media, illustrating the extent to which presence of Martian life or traces of its previous existence on the early Mars could affect the intellectual, philosophical or religious attitudes of humans, with respect to their belief that life originated on the Earth.

Regarding the spreading of terrestrial life on other celestial bodies, in particular the terraforming of Mars, the irreversibility of such a process renders imperative a public debate of the kind already initiated by the Mars Society. Should a native life exist on Mars, do we have the right to impose ours on it? Should we consider bringing life onto a sterile planet, would it be more appropriate to use natural species or genetically modified organisms? Since this terraforming will have considerable implications for all of the mankind, it is of cardinal importance to hold a debate within the largest possible audience.

THE PROJECT

Symbols such as pictures are easily understandable. They have been and are always used to communicate between people of different education levels, cultures, ages, and genders. To symbolize our present day civilization, we have chosen to represent mankind by the image of a hand. Why precisely the hand? Well, a picture of a hand is an easily recognizable, almost universal, symbol that hardly varies with the race, the gender or the age of a human being. In our project, one of the different hands represented in Figure 1 was chosen as an anonymous signature of all humanity.

Figure 1. Pictures of Human Hands.



To convey our existence to other living creatures in the universe, we propose to encode this image into bacterial DNA

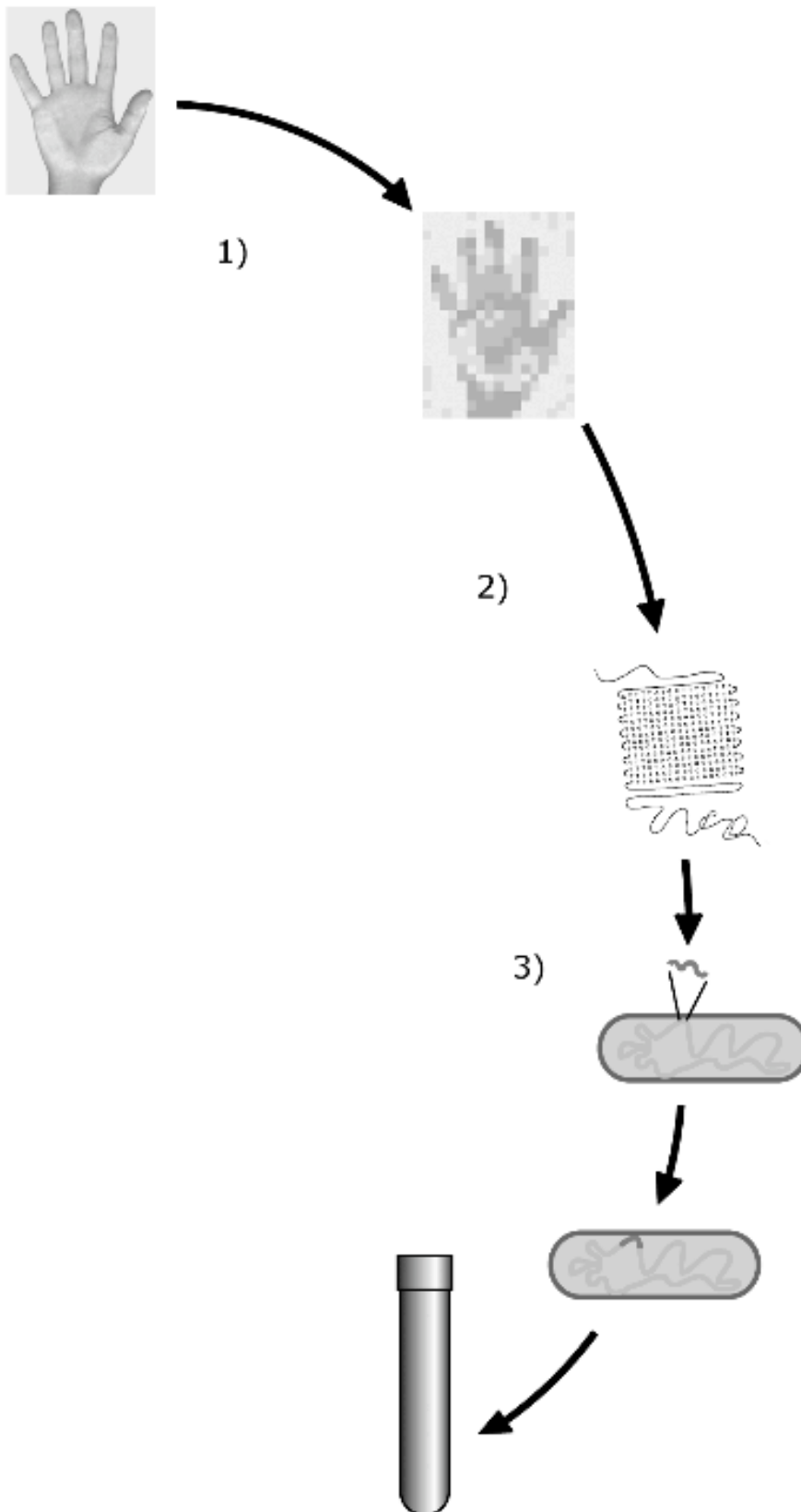


Figure 2. Encoding the Image into Bacterial DNA.
1) Translation of the Picture in Four Levels of Grey, 2) Traduction in DNA,
3) Transformation of Bacterial Cells.

DNA information is based on an arrangement of four nucleotides: Thymine (T), Adenine (A), Cytosine (C), and Guanine (G). During eons, the know-how needed for life was recorded into chromosome DNA. Read by specialized machinery, the information contained by most of the genes is translated into proteins, i.e. polymers made of 20 different amino acids. A gene encoding a protein consists of an arrangement of codons, each composed of three nucleotides. The 64 codons, with the exception of three of them devoted to punctuation symbols, are all encoding one of the 20 amino acids.

How to encode a two-dimensional picture into a linear DNA molecule? Since chromosomes are made of four different nucleotides, we decided to represent the picture by only four distinct levels of grey and to proceed as explained in Figure 2.

After pixelization into a picture consisting of 17 by 23 pixels, each characterized by one of the four levels of grey, the image was encoded as follows: we established a correspondence between the four levels of darkness and the four nucleotides. The hierarchy was established, primarily according to the number of hydrogen bonds involved in base pairing - Thymine and Adenine being associated by two hydrogen bonds, while association of Cytosine and Guanine requires three such bonds -, and secondly according to the molecular weight of the four nucleotides, i.e. 242.2, 267.2, 243.2, and 283.2 g/mole for T, A, C, and G, respectively. Thus, we decided to encode white, pale grey, dark grey and black pixels by T, A, C, and G, respectively.

Next we reduced the information contained in our image by transforming it into 17 by 23 pixels¹. The latter image was deliberately composed of prime numbers of rows and columns (Figure 2), a scheme developed by the Arecibo project sending in 1974 to a cluster of stars a binarized image symbolizing our solar system and its life (Figure 3, The Staff at the National Astronomy and Ionosphere Center, 1975). The DNA sequence corresponding to the message (see above) is given in Figure 2. Contrary to the relatively important Arecibo message², we have chosen an image with a simple content endowed, however, with a high symbolic meaning.

¹ http://www.unil.ch/igbm/mille_milliards.html

² http://www.ee.fit.edu/users/lpinto/Science/Reaching_Out/Arecibo.shtml



Figure 3. The Arecibo Message.

In 1974, the Arecibo radio telescope broadcasted a message to the globular cluster M13, located at a distance of 25'000 light years. To be easily decoded, the binarized message was made of an uneven number of rows and columns. The 1679-bit picture described from top to bottom: a counting scheme, five biologically significant atoms (H, C, N, O, and P), the structure of the four building blocks of DNA (a DNA strand containing the nucleotides A and C pairs to G and T belonging to the anti-strand), a picture of the molecule of DNA with an estimate of the number of base pairs in the human genome, a representation of a human being, the length of a human body, a description of the solar system specifying that humans live on the third planet, an estimate of the human population, and finally, a drawing of the Arecibo radio telescope and its dimensions (The Staff at the National Astronomy and Ionosphere Center, 1975).

The artificial, 391 nucleotides long, non-coding sequence will be inserted into the chromosome of *B. subtilis*, a spore forming bacterium non-pathogenic for men (Figure 4, summary of the process). Grown in a so-called sporulating medium, these engineered bacteria will yield spores (Figure 5, spores of *B. subtilis*).

One gram of spores of this bacterium contains 10^{12} cells, i.e. an equal number of copies of the encoded image. Less than one gram of this bacterial support would be sufficient to symbolically represent all the hands of presently living individuals, as well as of the past members of the human community.

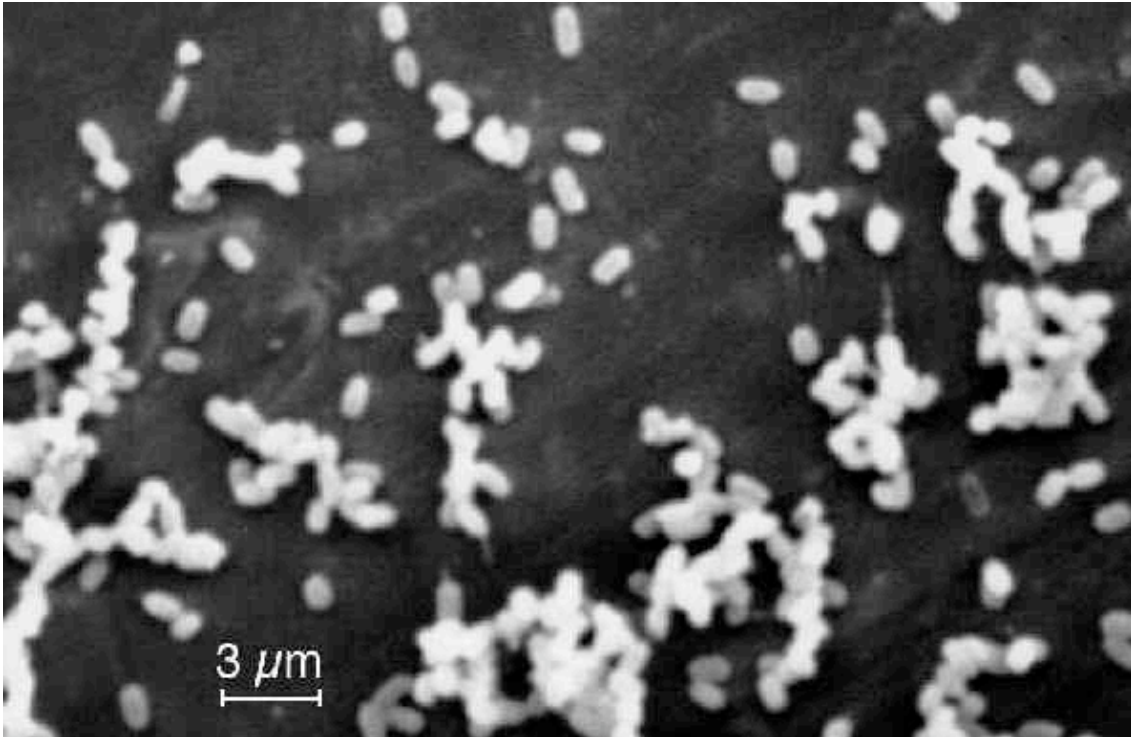


Figure 4. A Scanning Electron Microscope Picture of Freeze-Dried Spores of *B. subtilis* 168. (Credit: Nicolas Meisser and Olivier Braissant)

SCIENTIFIC BACKGROUND

Why choose bacteria? Bacteria played a central role in the evolution of life on the Earth. All the oldest terrestrial sediments, 3.5 and 3.85 billion years, capable of recording cellular metabolisms and fossils, did actually contain traces of life (see for example Schopf, 1993). Single cell organisms, known as prokaryotes, were apparently the only examples of life, during the first billion of years of life existence, on the Earth. The entire biochemistry presently used in the living world, i.e. from photosynthesis and respiration to biosynthesis of amino acids and antibiotics, was developed by prokaryotes. As soon as they were present on or within the terrestrial crust, they gradually transformed their environment. For instance these true terraformers gradually converted the early terrestrial atmosphere, at that time similar to the Martian one, into a gaseous oxygen-containing envelope. Later, they were the living building blocks that, through endosymbiosis, generated the complex eukaryotic cell, the cellular unit of protists, fungi, algae, plants and animals.

A planetary crust, an ocean and an atmosphere similar to their early terrestrial counterparts were present on Mars, a few hundred million years earlier than on our planet, suggesting that the red Planet was suitable for life well before ours. During the end of the accretion of planetary bodies of the solar system, the heat produced by the impacts and the decay of radioactive molecules was high enough to allow a partial differentiation of planets and satellite: their atoms segregated into a planetary mantle and a core. Due to more favorable volume/surface ratio, smaller bodies of our solar system

cooled before the larger ones, explaining why the age of the crust was the oldest on the Moon, then on Mars, and finally on the Earth. A dense gaseous envelope is necessary to maintain liquid water on the surface of a planet. The Moon was too light to keep an atmosphere, but Mars, Venus and the early Earth were massive enough to retain one, mainly composed of CO₂. For instance, the planet altimetric data provided by the Mars Global Surveyor unveiled a putative shoreline of a past ocean on the Northern hemisphere of the red planet (Smith et al., 1999).

Should the analysis of samples, expected to be brought back in the near future by the two Mars sample return missions, confirm the claim of putative life on early Mars, we will have to explain its emergence? A Martian life using building blocks different from their terrestrial counterparts would imply that different forms of life could have appeared anywhere in the universe. However, a similar biochemistry of Martian and terrestrial life would strongly suggest that biological know-how could be exchanged and shared by different celestial bodies. Recent experiments clearly reveal that bacteria entrapped in small meteoroids are able to withstand the launch acceleration (10'000 g's) (Roten et al., 1998 a & b; Roten et al., 1999 a & b; Mileikowsky, 1997), the reentry (300 g's) and the final free fall impact (few thousand g's). Coupled to their resistance to vacuum (Portner et al., 1961; Mitchell and Ellis, 1972), low temperatures, radiations (Mileikowsky, 1998), stay of million years in amber, these properties support the possibility that bacteria could well have travelled alive in space as already proposed in the 19th century by Richter, von Helmolz, and Kelvin (Roten et al., 1998 a & b).

The claim that *Bacilli* were revived after a dormancy of million years (Cano and Borucki, 1995) strongly suggests that, once encoded in spores of *B. subtilis*, the substratum of the picture of a hand would last for such a period. Should it be confirmed that bacteria could be exchanged between celestial bodies, the use of the terrestrial/bacterial/biological know-how to terraform Mars would actually correspond to an acceleration of a process occurring naturally in the universe.

The image of a hand could be used as a flag for any possible future terraforming. It could be first deployed on the Martian ground. Subsequently, when the explorers will passively contaminate the planet crust, starting a passive terraforming, a human artefact, corresponding to these engineered spores, could be seeded on the Martian surface. The display of the flag would hint that an encrypted message is present. The artificial nucleotide sequence, integrated into the chromosome of an organism designed not to be used by a living cell, has no biological function. Easy to recognize from a minimum of set of information, the image of a hand is perfectly suitable to be encoded and deciphered in our conditions. A trained observer can recover this information by deciphering the bacterial DNA and, after an analytical process, interprets the image as a by-product of a civilization capable to manipulate genetic information.

HISTORICAL AND CULTURAL BACKGROUND

In human history, images of hands belong to the oldest remnants of cultural expression. Imprints of hands like those presented in Figure 6, found in the cave of

Pech-Merle in France, are more than 20'000 years old¹. Images of hands were found in Africa, Australia, and elsewhere, revealing that this symbol is widely spread as a universal archetype.



Figure 5. The Hand of Pech-Merle.

To encode the symbol in DNA provides additional information, i.e. that our civilization is mastering the genetic manipulation. Such a know-how, presently used to study life, was however developed, in a rather empirical form, already 10'000 years ago, when Mesopotamian settlers succeeded in selecting wheat, a complex hexaploid organism, i.e. an assortment of genes originating from three different organisms. Planting cereals was a seminal step in human history. It relieved more and more people from food harvesting or hunting duties, allowing them to participate in creation of new technologies, knowledge, or cultural activities. The transformation of a population of harvesters and hunters into that of farmers was one of the key steps in the development of a civilization, a step that has occurred in different places of the world. In addition of symbolizing the early steps of our civilization, the image of a hand reminds us of our childhood.

Finally, a spur of an open hand reveals a passage of someone. The tradition of leaving a trace of one's passage is a behavior universally spread among mankind. Modern and contemporary artists explored with obstination and used all the resources of print. Rodin onwards and largely from the time of Marcel Duchamp, many artists worked

¹ <http://www.crdi.fr/~a.lot.of.france/lp01.htm>

with the concept of the imprint: parts of the body or objects were used from multiple aesthetic and conceptual perspectives. Who are some of the most famous: Jasper Jones, Yves Klein, Richard Long, the artists of the Land-Art, Support-Surface, Giuseppe Penone and the Arte Povera, Gabriel Orozco (Didi-Huberman, 1997), etc.

DISCUSSION

Our multidisciplinary project could work at three different levels. First, an offshoot of this project is ready to be used: a flag could be the symbol of the future Mars exploration (Figure 6). This image could be more elaborated by using, for instance, red, green, and blue, the three colours of the Robinson trilogy.

A project like the Martian exploration needs a universal symbol, a label that should certify that all individuals on the Earth are concerned by this task. Similarly in the recent past, it was first proposed for the first lunar exploration mission Apollo 11 to deploy the UNO flag on the Moon, showing that people, in the name of mankind, came with peaceful intentions. Second, our project, to be fully completed, should provoke a multidisciplinary debate. The open hand symbol, encoded in a bacterial chromosome, will have to mean that the mankind does understand the importance of life on the Earth, as well as its origins. Third, displayed on the red planet, at the beginning of the Mars terraforming, will highlight the responsibilities taken by humans in this adventure. It should be a label, denoting that the enterprise has been freely and widely debated by men, within the limits of their hopefully ever-progressing consciousness of what this adventure may bring to humanity.



Figure 6. The Flag Presented by Claude-Alain Roten.

(Courtesy of the organizers of the Second Annual Convention of The Mars Society)

Note added in proof

During the writing of this article, we learned that Joe Davis used 15 years ago bacteria to encode a symbol: the Microvenus icon (Gibbs, 2001)¹.

REFERENCES

Cano, R. J., and Borucki, M. K., "Revival and identification of bacterial spores in 25- to 40-million-year-old Dominican amber," *Science*, Vol. 268, No. 5213, May 19, 1995, pp. 1060-1064.

Didi-Huberman, G., *L'empreinte*, Editions du Centre Georges Pompidou, Paris, 1997.

Gibbs, W. W., "Art as a Form of Life," *Scientific American*, Vol. 284, No. 4, April 2001, pp. 28-29.¹

McKay, D. S., Gibson, E. K. Jr., Thomas-Keprta, K. L., Vali, H., Romanek, C. S., Clemett, S. J., Chillier, X. D. F., Maechling, C. R., and Zare, R. N., "Search for past life on Mars: possible relic biogenic activity in Martian meteorite ALH84001," *Science*, Vol. 273, No. 5277, August 16, 1996, pp. 924-930.

Mileikowsky, C., "Can spores survive a million years in the radiation in outer space? Part I: protection against photons above 0.5 keV," in *Astronomical and Biochemical Origins and the Search for Life in the Universe, Proceedings of the 5th International Conference on Bioastronomy*, IAU Colloquium No. 161, Capri, July 1-5, 1996, pp. 545-552, edited by C. B. Cosmovici, S. Bowyer, and D. Werthimer, Editrice Compositori, Bologna, 1997.

Mileikowsky, C., Cucinotta, F. A., Wilson, J. W., Gladman, B., Horneck, G., Lindegren, L., Melosh, J., Rickman, H., and Valtonen, M., "Natural transfer of viable microbes in space; part 1: from Mars to Earth and Earth to Mars," abstract presented at the Founding Convention of the Mars Society, Boulder, CO, August 13-16, 1998.

Mitchell, F. J., and Ellis, W. L., "Surveyor 3: bacterium isolated from lunar-retrieved television camera," in *Analysis of Surveyor 3 Material and Photographs Returned by Apollo 12*, pp. 239-248, National Aeronautics and Space Administration, Washington DC, 1972.

Portner, D. M., Spiner, D. R., Hofmann, R. K., and Phillips, C. R., "Effect of ultrahigh vacuum on viability of microorganisms," *Science*, Vol. 134, No. 3495, December 22, 1961, p. 2047.

Roten, C.A. H., Gallusser, A., Borruat, G. D., Udry, S. D., and Karamata, D., "Impact resistance of bacteria entrapped in small meteorites," *Bulletin de la Société Vaudoise des*

¹ <http://www.sciam.com/2001/0401issue/0401profile.html>

Sciences Naturelles, Vol. 86., fasc. 1, November 1998a, pp. 1-17. Or http://www.unil.ch/igbm/bsvsn_bact&impact.html

Roten, C. A. H., Gallusser, A., Borruat, G. D., Udry, S. D., Niederhäuser, G., Croxatto, A., Blanc, O., De Carlo, S., Mubenga-Kabambi, C. K., and Karamata, D., "Interplanetary biological transfer of bacteria entrapped in small meteorites: analysis of bacterial resistance to impact in ballistic experiments," proceedings of the Founding convention of the Mars Society, Boulder, CO, August 13-16, 1998, vol. 2, pp. 485-500, edited by R. M. Zubrin and Maggie Zubrin, Univelt, California, USA, 1998b.

Roten, C. A. H., Gallusser, A., Borruat, G. D., Udry, S. D., Mubenga-Kabambi, C. K., Barblan, J. L., and Karamata, D., "Survival of organisms in ultracentrifugation experiments similar to the mechanical stresses endured during an interplanetary stone-borne transfer," oral presentation at Life Odyssey Symposium, 7th European Symposium on Life Sciences Research in Space, ESA, Maastricht, NL, May 29 - June 2, 1999a.

Roten, C. A. H., Udry, S. D., Borruat, G. D., Mubenga-Kabambi, C. K., Barblan, J. L., Braissant, O., Gallusser, A., and Karamata, D., "Possible interplanetary biological stone-borne transfers will be challenged by the biochemical analyses of returned samples of Mars," oral presentation at the second annual convention of the Mars Society, University of Colorado, Boulder, CO, August 12-15, 1999b.

Schopf, J. W., "Microfossils of the early archean apex chert: new evidence of the antiquity of life," *Science*, Vol. 260, No. 5108, April 30, 1993, pp. 640-646.

Smith, D. E., Zuber, M. T., Solomon, S. C., Phillips, R. J., Head, J. W., Garvin, J. B., Banerdt, W. B., Muhleman, D. O., Pettengill, G. H., Neumann, G. A., Lemoine, F. G., Abshire, J. B., Aharonson, O., Brown, C. D., Hauck, S. A., Ivanov, A. B., McGovern, P. J., Zwally, H. J., and Duxbury, T. C., "The global topography of Mars and implications for surface evolution," *Science*, Vol. 284, No. 5419, May 28, 1999, pp. 1495-1503.

The Staff at the National Astronomy and Ionosphere Center, "The Arecibo Message of November 1974," *Icarus*, Vol. 26, 1975, pp. 462-466.

Zubrin, R. M., and Wagner, R. S., *The Case for Mars, The Plan to Settle the Red Planet and Why We Must*, The Free Press, New York, London, Toronto, Sydney, Singapore, 1996.

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