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The Tatahouine Meteorite: A Case Study of Life Under Extreme Conditions

Philippe Gillet (pgillet@ens-lyon.fr)[1], **Wafa Achouak**[2], **Jean-Alix Barrat** (barrat@univ-angers.fr)[3], **Karim Benzerara** (benzerar@lmcp.jussieu.fr)[4], **François Guyot** (francois.guyot@lmcp.jussieu.fr)[4], **Thierry Heulin** (theulin@cea.fr)[2], **Laurence Lemelle** (llemelle@ens-lyon.fr)[1] & **Maurice Lesourd**[5]

[1] Lab. Sciences de la Terre, ENS Lyon, 46, allée d'Italie, 69364 Lyon Cedex 07, France
[2] Lab. d'Ecologie Microbienne de la Rhizosphère, UMR 163 CNRS-CEA., 13108 Saint-Paul-Lez-Durance Cedex., France
[3] Université d'Angers, Faculté des Sciences d'Angers, 2 Bd Lavoisier, 49045 Angers Cedex, France
[4] Laboratoire de Minéralogie-Cristallographie et Institut de Physique du Globe de Paris, 4 pla ce Jussieu, 75252 Paris cedex, France
[5] Service Commun de Microscopie Electronique, Faculté de Medecine, Rue Haute de Reculée, 49045 Angers Cedex, France

We present a study of the textural signature of terrestrial weathering and related biological activity in the Tatahouine meteorite. The fall of the Tatahouine achondrite was observed on 27 June 1931 in the Tunisian desert. Hundreds of fragments were dispersed over a small strewnfield (<1 km 2) on a hill slope composed of Jurassic limestones with a dessertic sandy soil. Many fragments were recovered that same day and sent to the Muséum National d'Histoire Naturelle in Paris. The samples ranged from nearly 2 kg to 1 g or less. They were composed essentially of large orthopyroxene crystals (up to 3 cm) with accessory chromite, iron sulfide, metal and glass inclusions. The strewnfield was revisited in 1994 and several small samples (<50 g) were recovered by sifting the first few centimeters of the soil. We examined samples and thin sections of Tatahouine collected in 1931 and 1994. The fractures in the 1931 samples are empty and the surfaces are bright. Many of the fractures in the 1994 samples contain yellowish to light orange mineral aggregates.

Scanning and transmission electron microscopy images obtained on the weathered samples of the Tatahouine meteorite and surrounding soil show two types of bacteria-like forms lying on mineral surfaces: (1) rod-shaped forms (RSF) about 70-80 nm wide and ranging from 100 nm to 600 nm in length; (2) ovoidal forms (OVF) with diameters between 70 and 300nm. They look like single cells surrounded by a cell wall. Only Na, K, C, O and N with traces of P and S are observed in the bulk of these objects. The chemical analyses and electron diffraction patterns confirm that the RSF and OVF cannot be magnetite or other iron oxides, iron hydroxides, silicates or carbonates. The size of the RSF and OVF are below those commonly observed for bacteria but are very similar to some bacteria-like forms described in the Martian meteorite ALH84001. All the previous observations strongly suggest that they are bacteria or their remnants. This conclusion is further supported by microbiological experiments in which pleomorphic bacteria with morphology similar to the OVF and RSF objects are obtained from biological culture of the soil surrounding the meteorite pieces. The ^{16}S rDNA of the bacterial strain TTB 310 containing both OVF and RSF morphotypes was sequenced and only one DNA sequence was observed, demonstrating that both morphotypes represent the same bacteria. This sequence has been deposited in the GenBank database (N AF144383). This bacterial strain belongs to a new genus.

The present results show that bacteriomorphs of diameter less than 100 nm represent real bacteria or their remnants. They also show that unusually small bacteria are present in dessertic environments (with large temperature and hydric variations) and can colonize rocks of exotic origin. The present data also address general questions. What is the volume limit required for survival of an autonomous living organism? What are the criteria for assessing the presence of nanometric-sized remnants of life forms in rocks from the Earth and Mars?

The bacterial strain TTB 310 is used to study experimentally mineral-bacteria interactions. Slides of well polished and chemically homogeneous calcite, quartz and mica single crystals or equivalent powders are colonized by the model bacterial strain. Preliminary images using confocal microscopy show that the growth of bacteria modifies the mineral surfaces in very short times (dissolution features, neoformation of small mineral precipitates). Moreover, the way colonization occurs depends upon the nature of the minerals suggesting selection by the mineral surfaces.