

Hot Idea

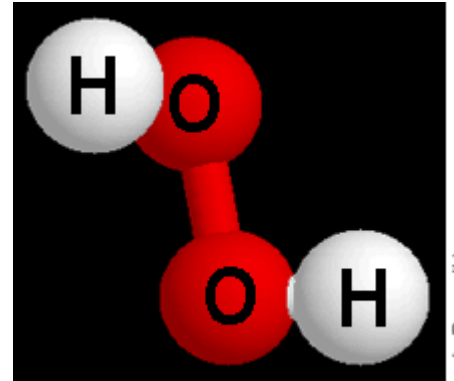
— posted June 19, 2007

Oxidants from Pulverized Minerals

--- Laboratory measurements of hydrogen peroxide produced from crushed basaltic minerals immersed in water have important implications for Martian and lunar dust.

Written by [Linda M. V. Martel](#)

Hawai'i Institute of Geophysics and Planetology



(From *Windows to the Universe*, artwork by Randy Russell.)

Joel Hurowitz (previously at State University of New York at Stony Brook and now at the Jet Propulsion Laboratory), Nick Tosca, Scott McLennan, and Martin Schoonen (SUNY at Stony Brook) studied the production of hydrogen peroxide (H_2O_2) from freshly pulverized minerals in solution. Their experiments focused on olivine, augite, and labradorite; silicate minerals of basaltic planetary surfaces, such as the Moon and Mars, that are exposed to the intense crushing and grinding of impact cratering processes. The H_2O_2 produced in the experiments was enough to adequately explain the oxidizing nature of Martian [regolith](#) first determined by the [Viking](#) Landers and the results suggest, for the first time, that mechanically activated mineral surfaces may be an important part of the overall explanation for the Viking Lander biology experiment results. Hurowitz and coauthors further showed that when the pulverized minerals are heat-treated to high temperature under vacuum (to cause dehydroxylation) there is almost a 20 times increase in H_2O_2 production, a result which may be highly relevant to lunar dust. These careful studies demonstrate the importance of and concern about reactive dusts on planetary surfaces from two standpoints: the health of astronauts on surface maneuvers who may inadvertently breathe it and the viability of possible Martian organic species to survive in such a corrosive, antiseptic surface environment.

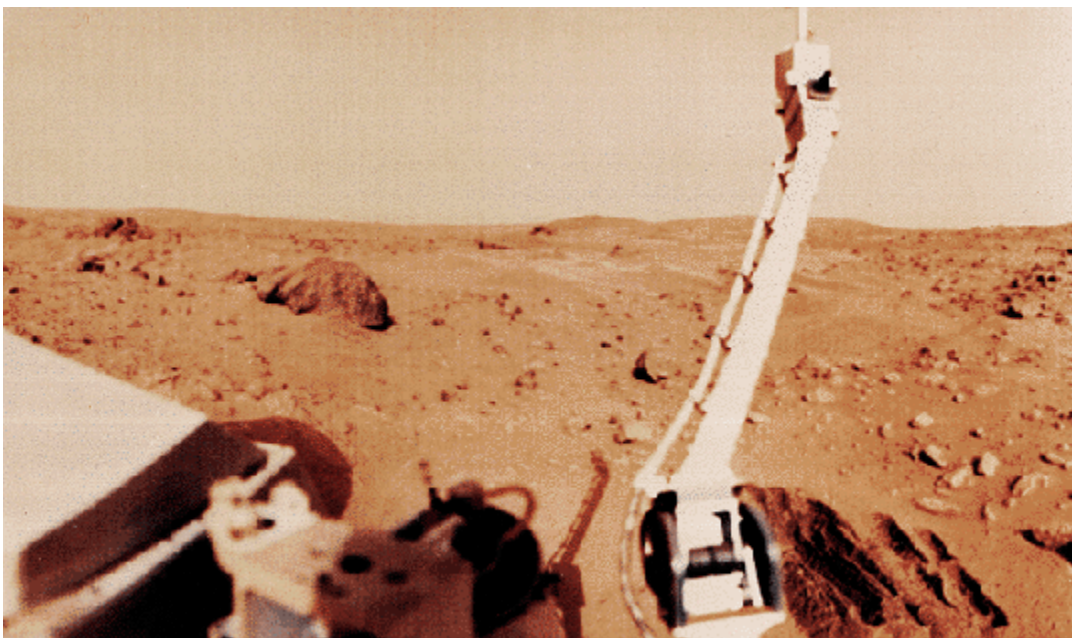
Reference:

- Hurowitz, J. A., Tosca, N. J., McLennan, S. M., and Schoonen, M. A. A. (2007) Production of Hydrogen Peroxide in Martian and Lunar Soils, *Earth and Planetary Science Letters*, v. 255, p. 41-52.

PSRD presents: Oxidants from Pulverized Minerals--[Short Slide Summary](#) (with accompanying notes).

Oxidizing Dust

From the time of the 1976 Viking Lander Gas Exchange (GEX) and Labeled Release (LR) experiments on the surface of Mars, researchers have known that Martian regolith is highly oxidizing. What the oxidant is and how it is formed has been debated ever since. Hydrogen peroxide (H_2O_2) was an early candidate and scientists using powerful telescopes finally reported in 2004 the detection of H_2O_2 in the Martian atmosphere. Yet, researchers discovered that the observed abundance of H_2O_2 in the Martian atmosphere was at least a factor of 1000 to 10,000 lower than the amount of oxidizer in the Martian regolith estimated from the Viking experiments at Chryse and Utopia Planitia.



Viking Lander 1, NASA press release image #77-HC-62

Trenches in the regolith at Chryse Planitia made by the Viking Lander 1 trenching arm can be seen in the lower right of this image, which was taken by the onboard camera. In the distance are low dunes composed of fine-grained material. Part of the Lander can be seen in the lower left, as well as the extended meteorology boom that was used for atmospheric experiments.

There have been many ideas proposed to explain the excess oxidant on the Martian surface, including biogenic processes or chemical changes above the Martian surface when dust devils and storms generate large-scale electrostatic fields. Hurowitz and coauthors addressed the issue by considering the effects that impact cratering has on planetary surfaces and how the resulting mechanically pulverized mineral dust would react with water to produce reactive oxygen species, such as H_2O_2 . Though the Martian surface is dry today, there is abundant evidence of a warmer and wetter past [see, for example, [PSRD](#) articles: [Magma and Water on Mars](#), [Gullies and Canyons, Rocks and Experiments: The Mystery of Water on Mars](#), and [Liquid Water on Mars: The Story from Meteorites](#)] and a chance for H_2O_2 production. Whenever water flowed or clouds drizzled, water could come in contact with reactive surface grains. On the Moon it never rains, but water would come in contact with dust grains when astronauts carried dust into their habitats and when they breathed the activated dust.

The idea of experimenting with reactive dusts follows naturally from years of medical research of human exposure to fine-grained carcinogenic quartz dusts and associated lung diseases. So, Hurowitz and coauthors used their cosmochemistry expertise to extend the study of H_2O_2 production from quartz dust to freshly ground silicate minerals that are known to exist in the basaltic crusts on Mars and the Moon.

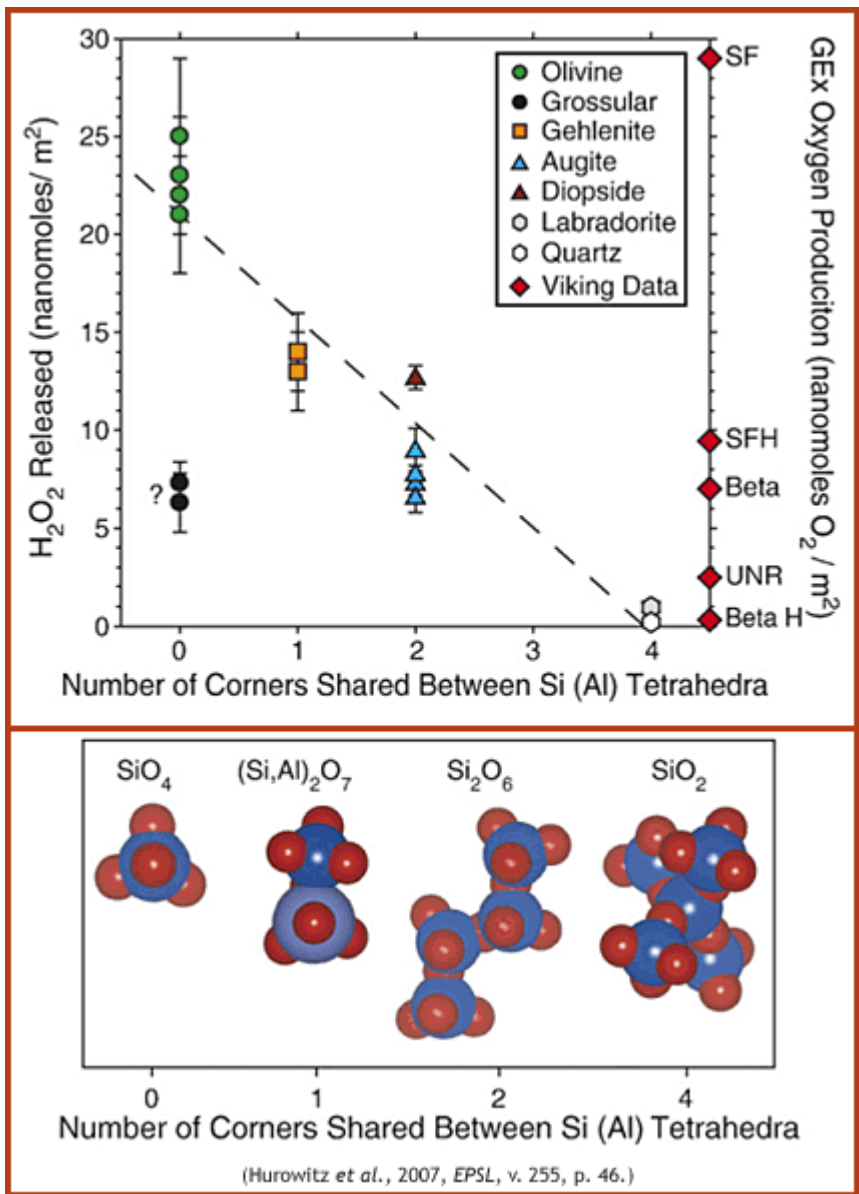
H_2O_2 from Mineral Powders in Solution

Hydrogen peroxide is a powerful oxidizer and disinfectant and has been referred to previously (e.g. Atreya and others) as a possible answer to why no organics have ever been detected by spacecraft on the surface on Mars. So the task laid out by Hurowitz and colleagues was to measure the quantity of H_2O_2 produced from a suite of basaltic silicate minerals common on Mars and the Moon, including olivine, augite, and labradorite. These minerals are pulverized into planetary regolith and dust during impact cratering events. Hurowitz and coauthors simply opted for a rock mill in the laboratory. They used an electron microprobe to determine the chemical compositions of their samples and then crushed the mineral samples into powders with grain sizes ranging from about 0.5 to 350 micrometers. These lab powders were slightly coarser-grained with a lower surface area compared to Martian regolith, but similar in grain size and surface area to lunar regolith. Each separate mineral

powder was mixed with deionized water, then filtered and analyzed for H₂O₂ concentration. This formation mechanism for H₂O₂ works because the process of grinding causes chemical bonds to break and the surfaces of the freshly pulverized minerals become sites of highly reactive radical species. These radical species are stable while dry, but produce H₂O₂ when immersed in water.

The researchers found that the production of H₂O₂ was not so dependent on grain size or surface area or amount of sample used in the experiments as on the actual structure of the mineral phase itself. Silica tetrahedra exist as separate, isolated structures or chains or three-dimensional structures. The isolated silica tetrahedra (e.g. olivine) share no corners, are known to be easily weathered (chemically altered), and produced the highest amounts of H₂O₂ during the experiments (see plot below).

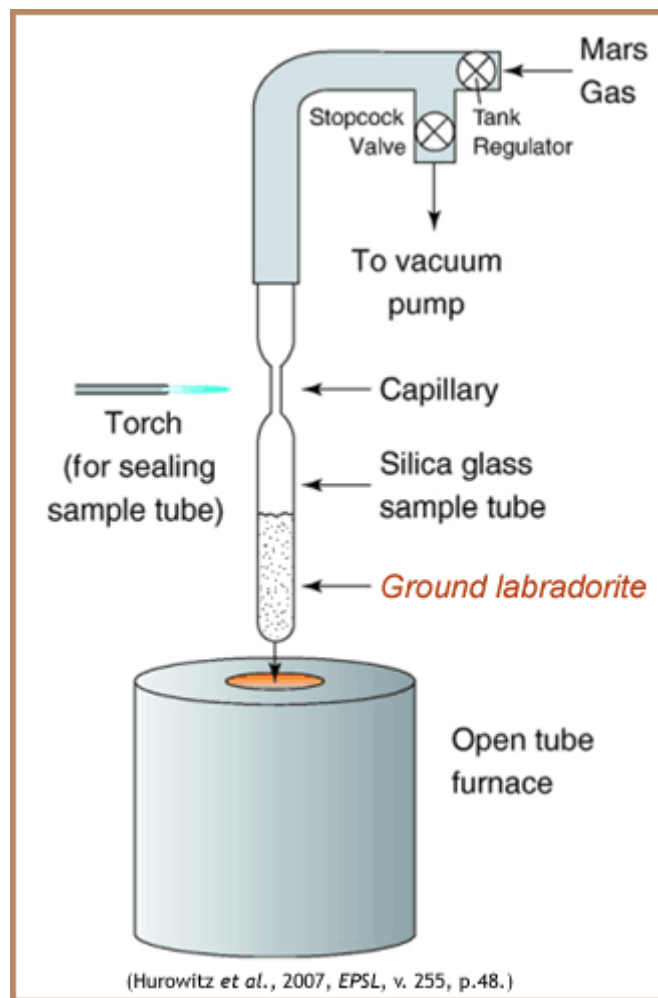
They computed how much H₂O₂ was produced by normalizing the total number of nanomoles of H₂O₂ in solution by the total surface area (m²) of the mineral powders. For example, olivine powder produced 21 to 25 nanomoles H₂O₂/m², augite produced 6.6 to 9.1 nanomoles H₂O₂/m², and labradorite produced about 1 nanomole H₂O₂/m². Interesting too, Hurowitz and colleagues measured <1 nanomole H₂O₂/m² produced from immersed quartz powders, which shows clearly that the basaltic silicate minerals are capable of forming higher concentrations of H₂O₂ in solution than is quartz under the same conditions of mechanical pulverization.



Experimental results are shown in the top graph. Hydrogen peroxide production (left axis) is plotted as a function of the number of shared SiO₄ corners in the silicate structure. Olivine, which shares no corners, reacts most readily. The right axis shows the results of the Viking GEX experiment, which measured the amount of oxygen produced. If we assume that one mole of H₂O₂ produces one mole of O₂, then this process explains the Viking results. The two vertical axes are expressed in per square meter because they are normalized to surface area of the mineral powders.

The lower portion of this figure shows what the different silica tetrahedra look like. Dark blue is silicon, red is oxygen, and light blue is aluminum.

Hurowitz and coauthors were also interested in how much H_2O_2 would form in solution from dehydroxylated mineral samples. Dehydroxylated minerals have surface-bound water (H_2O) and hydroxyl (OH) stripped away by heat treatment under vacuum (see diagram below). Two labradorite samples were dehydroxylated before being immersed in water and they yielded 24 ± 4 and 33 ± 3 nanomoles $\text{H}_2\text{O}_2/\text{m}^2$, quantities significantly greater than those produced by non-heated samples mentioned above. When the experiments were repeated on the dehydroxylated samples 30 minutes later the H_2O_2 values were slightly lower, which suggests to the research team that there might be another, shorter-lived oxidant produced when heat-treated mineral samples are immersed in water. They don't know what that other oxidant would be. The results, nonetheless, are significant for the Moon where plagioclase-rich regolith may exist in a partially dehydroxylated state that researchers attribute to impact heating in vacuum and high daytime surface temperatures.



This is a drawing of the heat treatment apparatus Hurowitz and colleagues used on the ground labradorite powders.

Looking Back to Viking Lander

Assuming that 1 mole of H_2O_2 results in 1 mole of O_2 , Hurowitz and colleagues' experiments show that their mineral powders released enough oxidant to adequately explain the Viking Lander Gas Exchange (GEX) results without having to invoke any other explanation for Martian regolith reactivity. They offer the simple explanation that oxidant was formed as a result of reactions between water and silicate mineral surfaces that had been crushed and activated by impact pulverization. Yet they concede that this mechanically-induced reactivity may really be only one contribution to the overall reactivity of planetary regolith.

Cosmochemical analyses show that the physical, optical, chemical, and mineralogical properties of Martian and lunar regoliths have clearly been modified since formation. For instance, on Mars, water, wind, and chemical weathering have changed material properties and have created new secondary alteration minerals (see **PSRD** article: [Pretty Green Mineral--Pretty Dry Mars?](#)) On the Moon, impact gardening and space weathering have caused changes in surface materials (see **PSRD** article: [New Mineral Proves an Old Idea about Space Weathering.](#)) How any of these subsequent modification processes and products have influenced the reactivity of the regolith materials and how deep the contamination goes are still to be determined.

Looking Forward

High concentrations of reactive oxygen species, such as H₂O₂, in planetary regoliths and dusts are of great concern and there is strong interest in characterizing them so that mitigation procedures can be worked out if fine-grained dust poses a health hazard to the respiratory systems of future astronauts working on the Martian or lunar surface. Furthermore for Mars, the radiation and oxidative environment have important ramifications on "life on Mars" surface and subsurface habitability issues.

Hurowitz and his coworkers' work was funded in part by NASA's Cosmochemistry program, which funds basic research in planetary materials. The applicability to life on Mars and to future missions to the Moon, Mars, and beyond shows how strongly basic research is connected to fundamental scientific questions and to mission planning.

Additional Resources

LINKS OPEN IN A NEW WINDOW.

- **PSRD presents:** Oxidants from Pulverized Minerals--[Short Slide Summary](#) (with accompanying notes).
- Atreya, S. K., Mahaffy, P. R., and Wong, A-S. (2007) Methane and Related Trace Species on Mars: Origin, Loss, Implications for Life, and Habitability, *Planetary and Space Science*, v. 55, p. 358-369.
- Atreya, S. K., Wong, A-S., Renno, N. O., Farrell, W. M., Delory, G. T., Sentman, D. D., Cummer, S. A., Marshall, J. R., Rafkin, S. C. R., and Catling, D. C. (2006) Oxidant Enhancement in Martian Dust Devils and Storms: Implications for Life and Habitability, *Astrobiology*, v. 6, p. 439-450.
- Hurowitz, J. A., Tosca, N. J., McLennan, S. M., and Schoonen, M. A. A. (2007) Production of Hydrogen Peroxide in Martian and Lunar Soils, *Earth and Planetary Science Letters*, v. 255, p. 41-52.
- Zent, A. P., and McKay, C. P. (1994) The Chemical Reactivity of the Martian Soil and Implications for Future Missions, *Icarus*, v. 108, p. 146-157.
- "Key to Martian Atmosphere Found" [Press Release](#) from the Joint Astronomy Centre regarding the 2004 detection of hydrogen peroxide in the atmosphere of Mars.
- Viking: A Laboratory on Mars [Website](#), nice overview from the Smithsonian National Air and Space Museum.



[[About PSRD](#) | [Archive](#) | [Search](#) | [Subscribe](#)]

[[Glossary](#) | [General Resources](#) | [Comments](#) | [Top of page](#)]

2007

psrd@higp.hawaii.edu

main URL is <http://www.psrdr.hawaii.edu/>