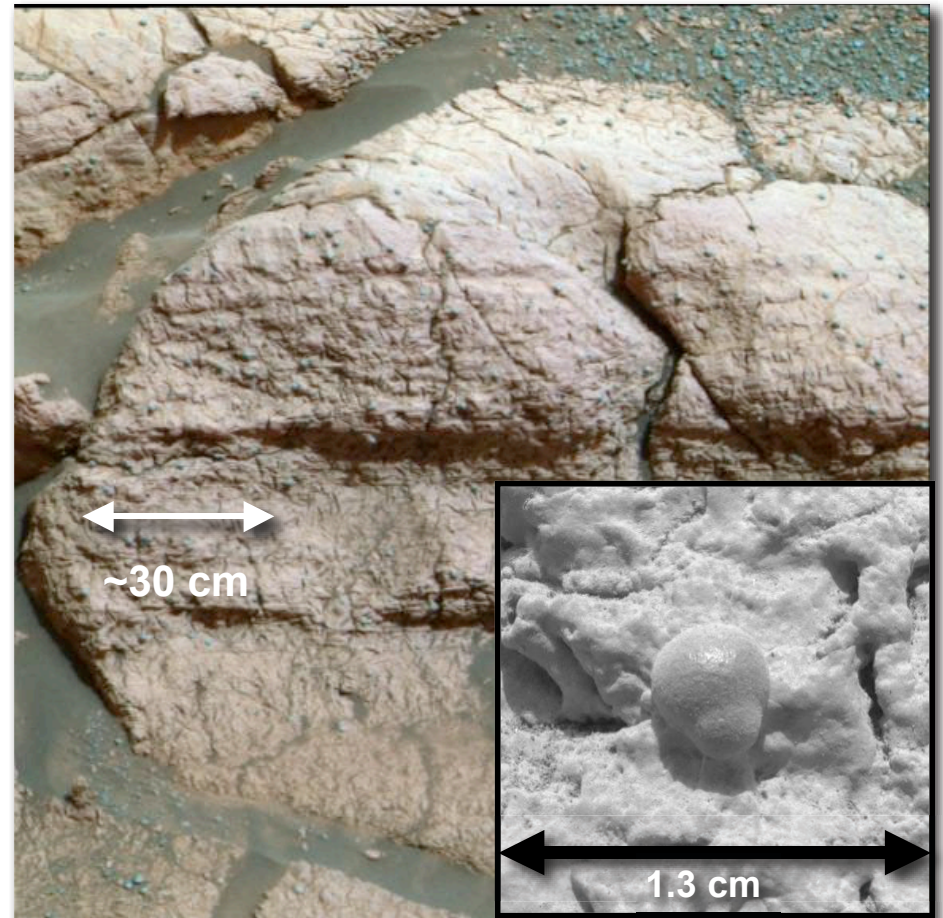


Did Sulfur Affect Mars Climate and Geology?

- Mars missions suggest that Mars once had a thick CO₂ atmosphere and liquid water
- On Earth these conditions lead to formation of *carbonate* rocks (like limestone)
- But Mars missions detect very little carbonate rock; instead Mars rovers find *sulfate* rocks



This rock outcrop studied by the Opportunity rover, contains the sulfur-bearing mineral jarosite. The inset shows a close-up of a hematite 'blueberry' believed to form due to water.

Why does Mars have more sulfur-rich rocks?

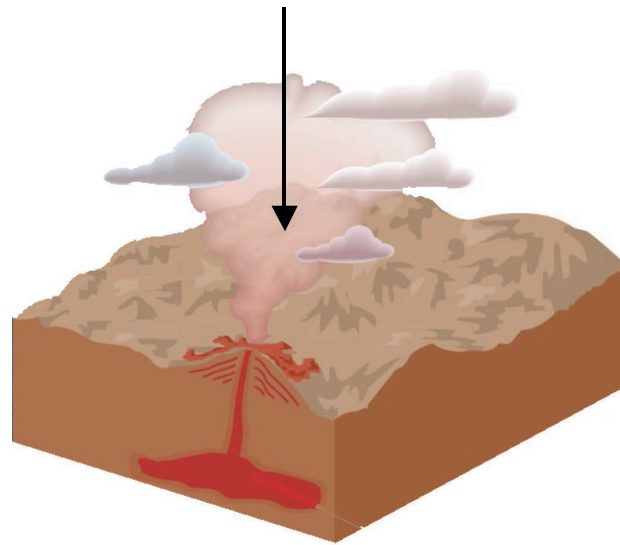
On Earth

- Volcanic SO_2 rapidly reacts with oxygen and water vapor
- CO_2 absorbed in water, forms carbonate rocks
- Little CO_2 left in our atmosphere - just enough for a mild greenhouse effect



The White cliffs of Dover, composed of carbonate

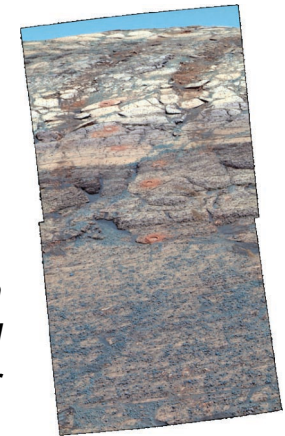
Volcanoes on Earth and Mars spewed out CO_2 and SO_2 along with H_2O



On Ancient Mars

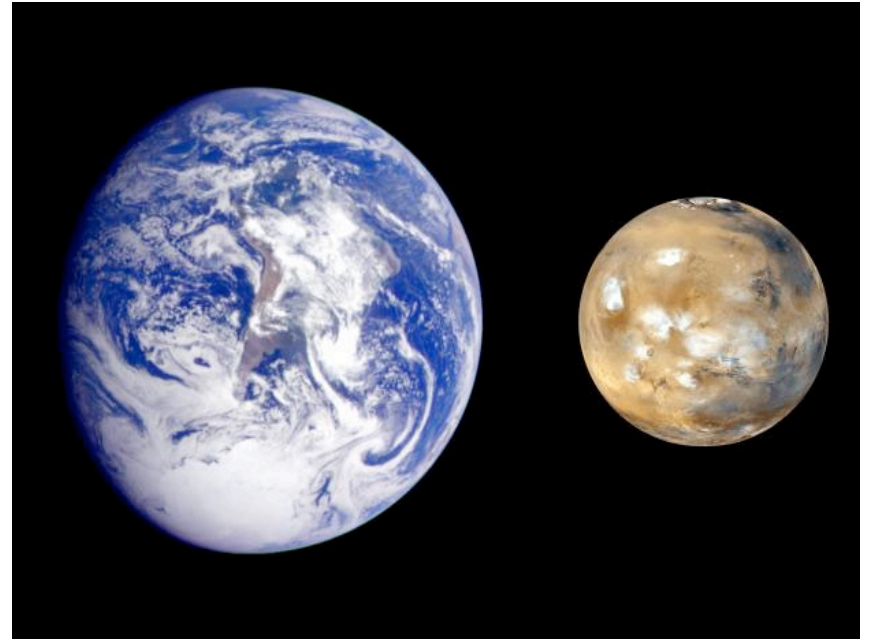
- Less oxygen and water vapor in atmosphere, so some SO_2 absorbed in surface water
- Water too acidic for carbonate formation, CO_2 stays in atmosphere
- Sulfur-bearing minerals form in water and make sulfate rocks

Endurance Crater, Mars, with countless 'blueberries' formed due to acidic liquid water



The Big Picture

- A minor gas (SO_2) can radically change Mars chemistry, preventing the major gas (CO_2) from forming carbonate rock as on Earth
- CO_2 in the atmosphere (instead of in rocks) plus H_2O and SO_2 gases provided lots of greenhouse warming for ancient Mars
- Planetary scientists continue to investigate why the paths of these two planets diverged billions of years ago



Sulfur gases may have affected the geology and climate of Mars enough to make it habitable in the past.

For more details...

Press Releases

- Marsdaily.com - 12/24/07 - “How Mars Could Have Been Warm And Wet But Limestone-Free”
<http://tinyurl.com/marswarmwetnolimestone>
- Marsdaily.com - 12/24/07 - “Sulfur Dioxide May Have Helped Maintain A Warm Early Mars”
<http://tinyurl.com/marsearlysulfur>

Images

- El Capitan and blueberry images courtesy of NASA/JPL
<http://photojournal.jpl.nasa.gov/catalog/PIA05478>
<http://photojournal.jpl.nasa.gov/catalog/PIA05474>
- White cliffs of Dover image:
<http://www.ippnw-students.org/OTT/DoverWhiteCliffs.jpg>
- Blueberries in Endurance Crater image courtesy of NASA/JPL
<http://marsrover.nasa.gov/gallery/press/opportunity/20040727a.html>
- Volcanic eruption diagram
Adapted from “The Cosmic Perspective”, by Bennett et al., Addison Wesley, Inc.
- Mars & Earth composite image courtesy of NASA/JPL
<http://photojournal.jpl.nasa.gov/catalog/PIA02570>

Source Article

(on-campus login may be required to access journals)

- Halevy et al., ‘A Sulfur Dioxide Climate Feedback on Early Mars’, *Science*, **318**, 1903 (2007), DOI: 10.1126/science.1147039.
<http://www.sciencemag.org/cgi/content/abstract/318/5858/1903>

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dpsdisc@aaas.org - <http://dps.aas.org/education/dpsdisc/> - Released 14 April 2009
