Violent eruptions in Mercury's past could hold clues to its formation

October 13 2014, by Nola Taylor Redd

Bright deposits around a line of volcanic vents suggest that the eruptions were explosive events. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Volcanoes on Mercury may have been more explosive than previously anticipated, and they may have erupted more recently, as well.

Scientists examining volcanic deposits on the surface of the planet using NASA's MESSENGER spacecraft found evidence of explosive activity as recently as a billion years ago. Previous studies of the cratering of other lava flows placed most volcanic activity at more than 3.5 billion years in the past.

Rocky planets like Mercury in orbit around other stars could have similar volcanic activity, releasing volatiles useful for the evolution of life at the surface. With temperatures ranging from -280 to 800 degrees Fahrenheit (-173 to 427 degrees Celsius), Mercury is not habitable, but similar rocky bodies around smaller, cooler stars would lie in their star's habitable zone, the region where liquid water could exist on the surface.

In fact, volcanism on the hot planet bears a strong similarity to volcanism on the Moon, which scientists say is surprising because of their differences.

"Both Mercury and the Moon are a lot smaller than the Earth, and so will have cooled more than Earth since their formation. For that reason, a lot of models would not predict volcanism within the last two billion years," lead author Rebecca Thomas of The Open University, in the United Kingdom, told Astrobiology Magazine by email.

Thomas added:

"The fact that they both have evidence for such volcanism, despite their very different internal structures and geological histories, suggests either that our thermal models are wrong, or that there is a common cause for the prolongation of such volcanic activity."

The research was published in the journal *Geophysical Research Letters* in September 2014.

Tiny glass beads

When NASA's Mariner 10 flew by Mercury in 1974, it captured features later identified as lava plains created by effusive volcanism, where lava flows from a vent in the ground. In 2009, studies by the MESSENGER probe identified irregular pits on the rocky planet with deposits that were redder than the planetary average when seen in visible and near-infrared wavelengths. Scientists identified the reddish material as pyroclastic deposits formed by explosive volcanism.

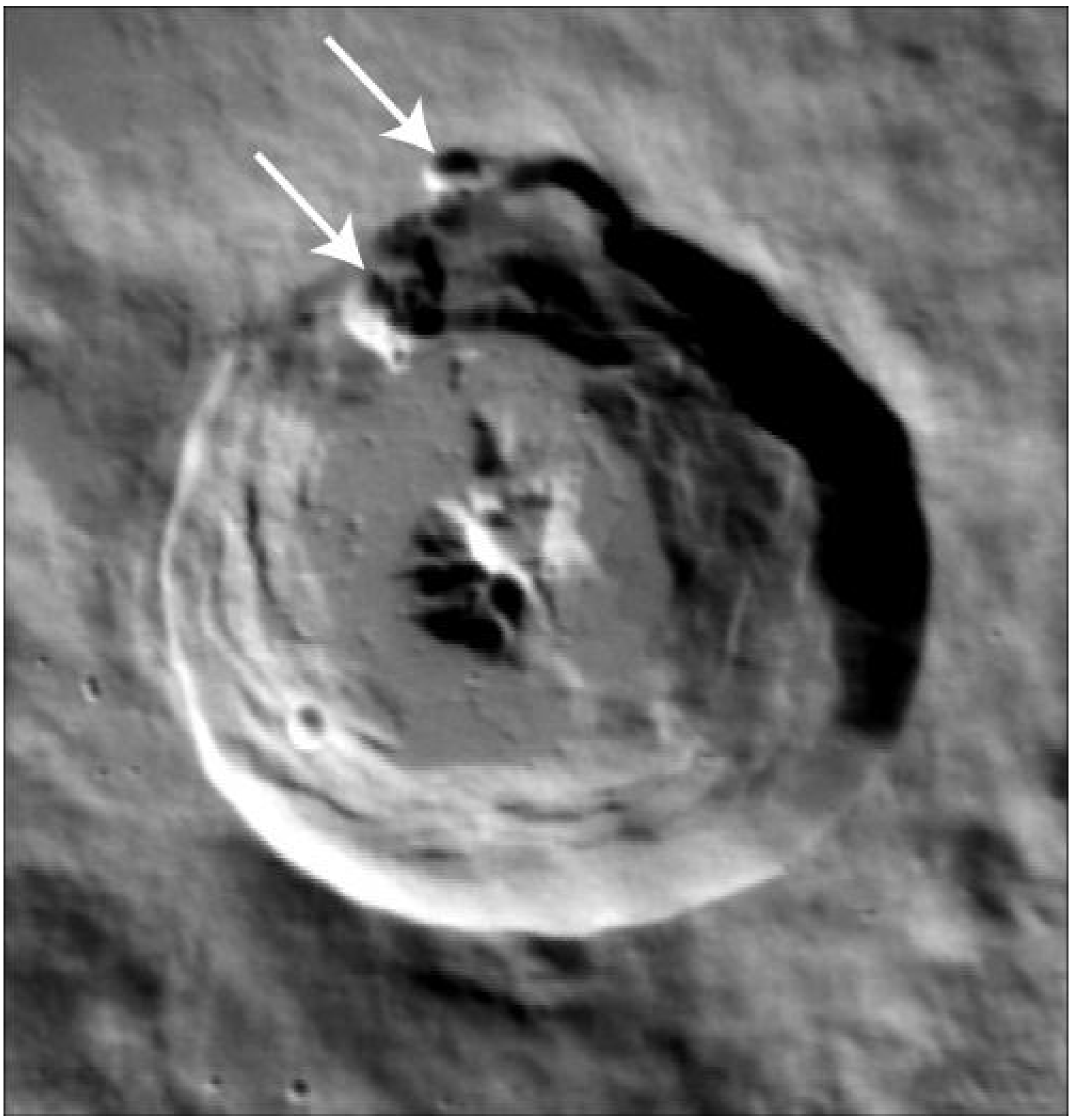
After identifying the first pyroclastic deposits, scientists searched other regions for indications of explosive volcanism. Thomas and her team found 150 groups of volcanic pits with bright red deposits to indicate that the lava had violently burst through the crust. Using craters to determine the age of the deposits, they found that they occurred between 4.1 billion years ago— not long after the planet's birth—up to about a billion years ago.

The volcanos formed aren't steep-sided cones like those often identified on Earth. Instead, the deposits form a ring around the vent out to approximately 3.5 miles (6 kilometers), and then a zone of thin deposits spread out about three times as far, Thomas said.

Although the deposits Thomas and her team searched for appear redder than the rest of the planet, they are so dark they would look black against the bright surface of the Moon, she said. Ejected material near the vents may have been so hot that it welded together on landing, looking more like lava flows or gobs of melted wax. Farther out, the magma fragments would have had more time to cool before landing, forming small glass spheres that resemble fine beads. On the Moon, these spherules come in many colors, depending on changes in the composition.

"When the Apollo 17 astronauts went to the Moon, they found orangecolored soil, and they realized that tiny glass spheres from a volcanic eruption were what made it look orange," Laura Kerber, of NASA's Jet Propulsion Laboratory, told Astrobiology Magazine in an email.

Kerber, who was not involved in the new research, studies explosive volcanism on Mars, Mercury and Earth.



Kuniyoshi, a fresh crater on Mercury less than a billion years old, contains volcanic vents in its rim and walls. Because the vents would not have survived the impact, scientists concluded they must be younger than the billion-year-old crater. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Identifying these features on Mercury has been what Kerber calls "a special challenge." On the Moon, the presence of iron allowed scientists to map different minerals. But on the surface of Mercury, there is so little iron that identifying the composition of the crust is more difficult.

"MESSENGER has several instruments, such as an X-ray spectrometer, and a gamma ray and neutron spectrometer, which allow us to learn about Mercury's composition in other ways," Kerber said. "Still, it would be great for us to have a sample of Mercury here on the Earth to study up close. Many amazing discoveries have been made using the pyroclastic beads that the Apollo astronauts brought back from the Moon."

"A Roman Candle firework"

Although most of the volcanism on Mercury took the form of slow-moving lava, some of it was quite violent.

"In explosive volcanism, gases that were originally dissolved in the magma rip it apart when it reaches the lower-pressure conditions of the planet's surface," Thomas said.

"Chunks of magma, blocks ripped from the vent wall, and finer ash are ejected violently. On Earth, these would be the most destructive eruptions."

Kerber compares the process to the physics involved in a carbonated beverage. In a can of soda, the carbon dioxide is pushed into liquid form while under high pressure. When the bottle is opened and the pressure released, bubbles form as the carbon dioxide jumps back into the gas phase.

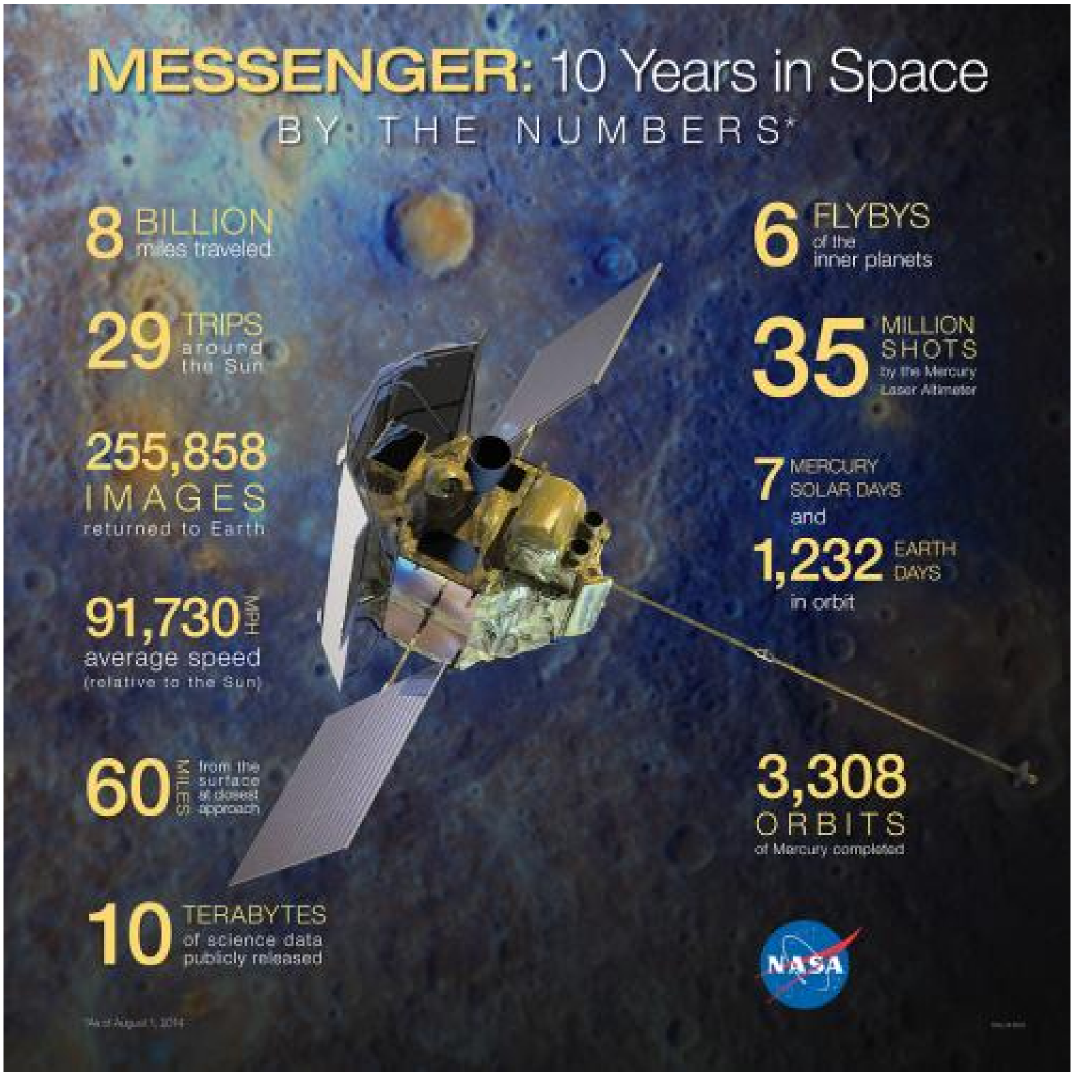
Materials known as volatiles, elements or compounds likely to enter the gas phase when heated, act similar to the soda's carbon dioxide. More volatiles result in more gas, making the eruption more likely to be explosive.

In addition, scientists think that an impact early in the planet's lifetime evaporated most of the crust, vaporizing most of its volatile components.

"So the presence of explosive volcanism on Mercury is a little bit surprising," Kerber said.

While the slow creeping lava from effusive eruptions might bear a strong resemblance to flows seen at the Kilauea volcano in Hawaii,the more explosive eruptions on Mercury would differ from those on Earth.

Mercury is a smaller planet, with lower gravity, which means material ejected from a volcano on the hot rocky planet would fly farther than if it spewed from an Earth-based eruption at the same speed.



MESSENGER celebrated a decade in space last August. Credit: NASA

Mercury also has almost no atmosphere, compared to the thick one surrounding Earth, which means that there would be no air pressure to keep the gas from spreading. As a result, Kerber said, the gases would expand more rapidly and explosively than they would on Earth. The lack of atmosphere would also keep the particles traveling in a straightforward trajectory, without the effects of turbulence or wind.

"On Mercury, you would not see billowing ash clouds as on Earth.

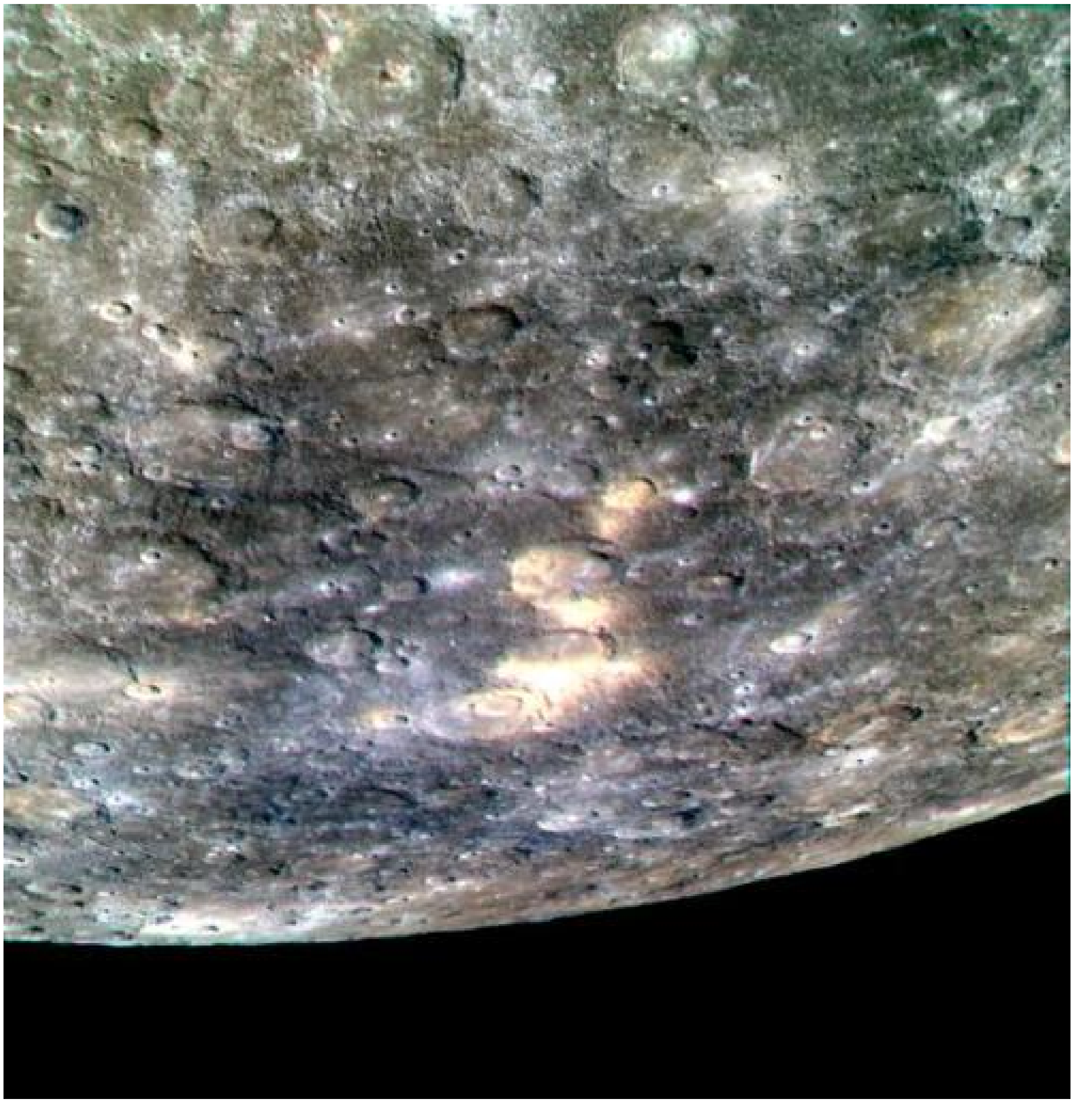
Instead, it would be like a Roman Candle firework, with glowing fragments spraying out in every direction," Thomas said.

Mercurys around other suns

Volcanism can help scientists understand a planet's composition, internal structure and even how it formed. As Mercury cools, it contracts, creating features known as "wrinkle ridges" as the crust pulls closer together. This contraction, along with the cooling, is one reason scientists thought it unlikely that volcanic activity would have continued into the later part of the planet's geological history, Thomas said.

Such deposits may be present on exoplanets—planets orbiting other stars—if they, too, are rocky bodies without an atmosphere. According to Kerber, the farther a planet is from a star, the more volatiles it is likely to have. Similarly, larger planets cool slower, also suggesting more volcanic activity.

Recent studies have suggested that rocky planets like Mercury orbiting stars smaller and dimmer than the sun—a class known as 'M dwarfs'—would be able to host photosynthesis on their surface.

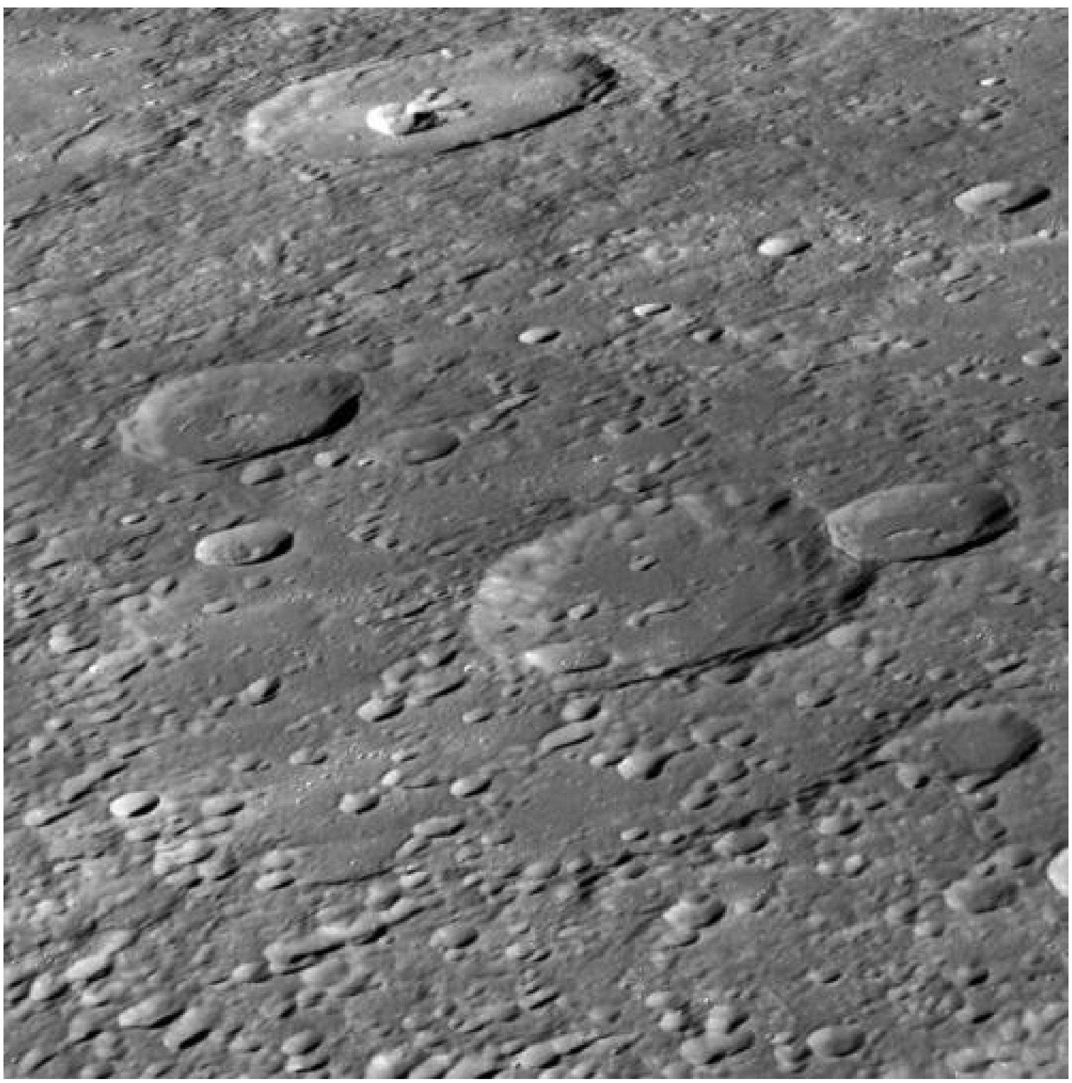


The fiery yellow spots shown in these images of Mercury are a series of pyroclastic vents believed to be one source of explosive eruptions on the planet. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

"If an exoplanet of a similar size were in its star's habitable zone, the heat from the volcanic eruption is a good source of energy, and the volcanic-bearing compounds it releases to the surface can be used as nutrients," Thomas said.

Exoplanets could also help to clear up the mystery of Mercury's formation, as scientists come to understand the internal composition of other small, close-orbiting rocky planets.

Mercury stands out from other planets in the Solar System because it has a massive iron core that dominates its interior. Less than 20 percent of the radius of the planet is taken up by the crust and mantle.



The irregularly shaped pit within the crater To Ngoc Van is thought to have formed through explosive volcanism. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Some models propose that the over-sized core is due to an impact early in its life—the same impact that scientists thought would have evaporated the majority of the volatiles when most of the crust and mantle were lost. Most of the iron remained, but in the planet's core rather than at its surface. Others suggest it formed this way due to its close orbit around the Sun.

"In fact, this is one of the most exciting things we could learn by looking at exoplanets that are also close to their star. Was a planet like Mercury inevitable at that distance from the Sun, or is it the result of a massive catastrophe?" Thomas said.

More information: Thomas, R. J., D. A. Rothery, S. J. Conway, and M. Anand (2014), "Long-lived explosive volcanism on Mercury," *Geophys. Res. Lett.*, 41, 6084–6092, DOI: 10.1002/2014GL061224.

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