Close Encounter: Galileo Eyes Io

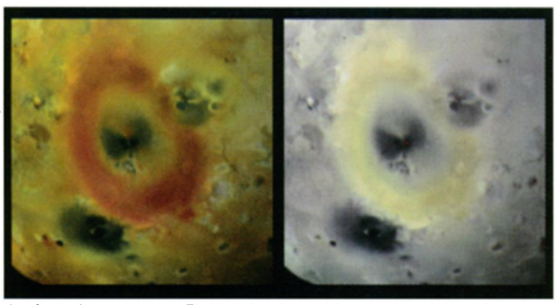
Craft records a hot time on a Jovian moon

By RON COWEN

In the dim reaches of the solar system, a rocky orb sizzles with volcanic hot spots and boiling lakes of lava. It belches sulfurous plumes hundreds of times taller than the World Trade Center.

Welcome to hell, also known as Jupiter's moon Io. About the size of Earth's moon, Io is pushed and pulled by the gravitational tug-of-war between Jupiter, on one side, and two of its large moons, Ganymede and Europa, on the other. The enormous stresses flex and heat Io. Its convulsions qualify it as the most volcanically active body in the solar system.

On Oct. 10, the Galileo spacecraft, which has toured Jupiter and its moons for 4 years, braved bombardment by the planet's intense radiation belts and swooped within 611 kilometers of Io's surface (SN: 10/30/99, p. 276). Images and spectra taken during this flyby represent the closest inspection of Io since Voyager discovered the moon's volcanic plumes 20 years ago.



Images: NASA/JPL

Left: Io's volcano Pele, depicted in approximately true color, shows red ring of sulfur dioxide deposited by the volcano's plume. Right: In this false-color view of Pele, the dark red dot indicates that at the heart of the volcano lava is hot enough to be visible in daylight.

Last month, at a press briefing in Washington, D.C., NASA unveiled images from the close encounter.

"Our view of this [moon] has changed dramatically in just the past few weeks," says Galileo project scientist Torrence V. Johnson of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif. The current volcanic eruptions glimpsed on Io may resemble those that raged on Earth in the distant past, he adds.

The enormously hot lavas on Io, which reach temperatures as high as 1,500°C, are thought to be rich in magnesium and as runny as olive oil. Lavas this hot were once relatively common on Earth, but not for the past 2 billion years, says Galileo scientist Alfred S. McEwen of the University of Arizona in Tucson

"Io is the next best thing to traveling back in time to Earth's earlier years," notes Johnson.

The new images focus on three active volcanoes near Io's equator: Pele, Loki, and Prometheus. Pele sports Io's largest plume, more than 400 km high. There, Galileo recorded a lone hot spot glowing in the nighttime sky. The spot has very little cool lava around it, indicating that Pele is steadily erupting. Lava flows that result from intermittent eruptions tend to be surrounded by low-temperature lava.

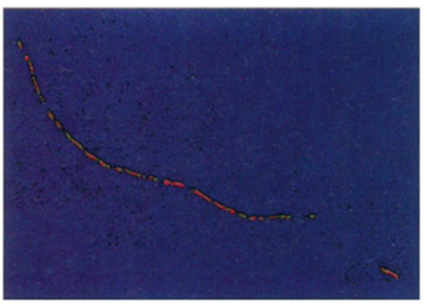
Scientists speculate that a lava lake, confined to a basin or caldera, surrounds and controls Pele's hot spot. The lake, suggests McEwen, is constantly being turned over, exposing fresh lava to the surface. In this way, the hot spot retains its high temperature and compact appearance.

Galileo found another curious feature at Pele. Images reveal a sinuous, curving line of hot, fresh lava, no more than a few minutes old. Some 10 km long and 50 meters wide, the line may mark the edge of the lava lake where it presses against a rocky wall and breaks up, McEwen says. Hawaii's mammoth Kilauea volcano shows the same structure on a much smaller scale.

"What we're seeing at Pele confirms that there's a lava lake in the caldera there, but 100 times wider than those in Hawaii," says McEwen.

Among the more than 100 volcanic powerhouses on Io, Loki stands out from the crowd. The most energetic volcano known in the solar system, it generates more heat than all of Earth's active volcanoes combined. The new images suggest that this volcanic Schwarzenegger has a caldera of cooled lava larger than the state of Maryland.

"What we think we're seeing at Loki is crusted-over lava that may be a month or perhaps a year old," notes Galileo researcher Rosaly Lopes-Gautier of JPL.



The curved outline is fresh lava along the walls of the caldera, or volcanic depression, at Pele. Scientists report the caldera is filled with boiling lava covered, except at the edge, by a cooler crust.

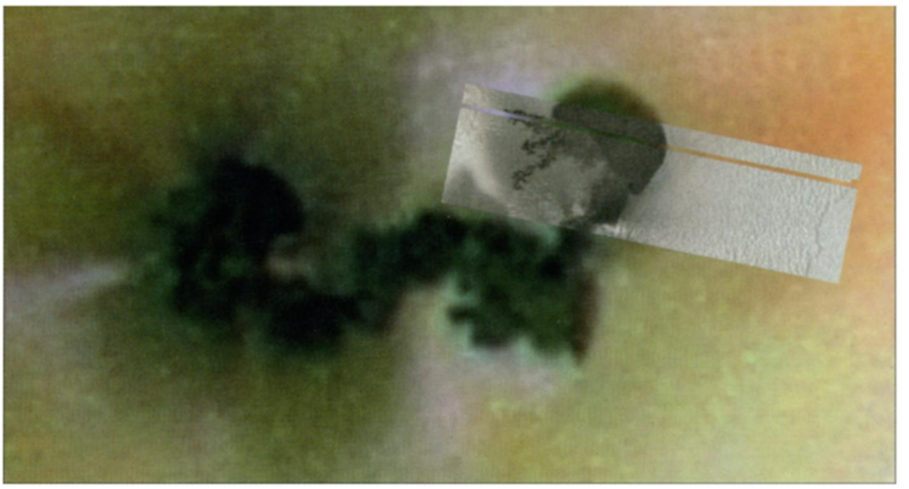
Galileo also obtained some puzzling new images of Prometheus. The Voyager spacecraft first spied a plume there in 1979. A few years ago, Galileo revealed a flow of lava from this volcano, as well as a 75-km-tall plume. Surprisingly, this plume appeared 100 km west of the earlier plume.

The newest images pin down the sites on Prometheus where lava is erupting, advancing, and producing plumes. However, they don't solve the puzzle of the plume Galileo found a few years ago.

That plume bears a striking resemblance to the one seen by Voyager, and planetary scientists believe the two are related. It's unlikely that separate volcanoes could fuel nearly identical plumes, says geologist Sue Kieffer of Kieffer & Woo in Palgrave, Ontario.

"We've never had anything on Earth like this, where a plume maintains the same shape, the same dimensions, but all of a sudden, 20 years later, it's in a different place," she notes.

McEwen speculates that the lava from Prometheus travels underground within channels known as lava tubes. Galileo sees a hot spot at the same location as the plume, as well as a dimmer spot where



Close-up view of part of Io's Prometheus volcano overlays an earlier, less detailed color image. The pictures reveal a lava-filled caldera, located at the northeast (upper right) end of the prominent dark feature. The new image also shows dark lava flows and a lumpy surface covered with sulfur-rich snow.

Voyager had previously glimpsed a plume.

The images, says Kieffer, "fit in quite well with the movement of the plume. Where we see the brightest hot spot is probably where lava is coming out of the tube."

Lava inside the underground tube heats a nearby layer of liquid sulfur dioxide, converting it to a vapor that forms the plume, McEwen suggests.

The new Galileo observations indicate that sulfur dioxide on Io plays the same role in making plumes that water does on Earth, says Carl B. Pilcher, director of solar system exploration for NASA in Washington, D.C. Io's lava vaporizes sulfur dioxide to drive towering plumes just as Earth's lava vaporizes water to power geysers like Old Faithful.

Eventually, sulfur dioxide vapor falls back onto Io's surface as snow. Images and spectroscopy reveal that a dark ring surrounding Prometheus is made of frozen sulfur dioxide.

The close-up images also provide new details about Io's mountains, some of which tower 16 km, taller than any on Earth. Concentric ridges covering Io's mountains and surrounding plateaus suggest that these elevated features don't last forever but collapse under the force of gravity, generating huge landslides. On Mars, the region just north and west of the mountain Olympus Mons shows similar ridges.

"The mountains [on Io] may be forming and falling apart faster than we imagined," says McEwen. Although volcanoes don't directly drive mountain formation, "the exciting thing to me is that the style of volcanism and mountains may go together in explaining what's happening in Io's crust and mantle," he notes.

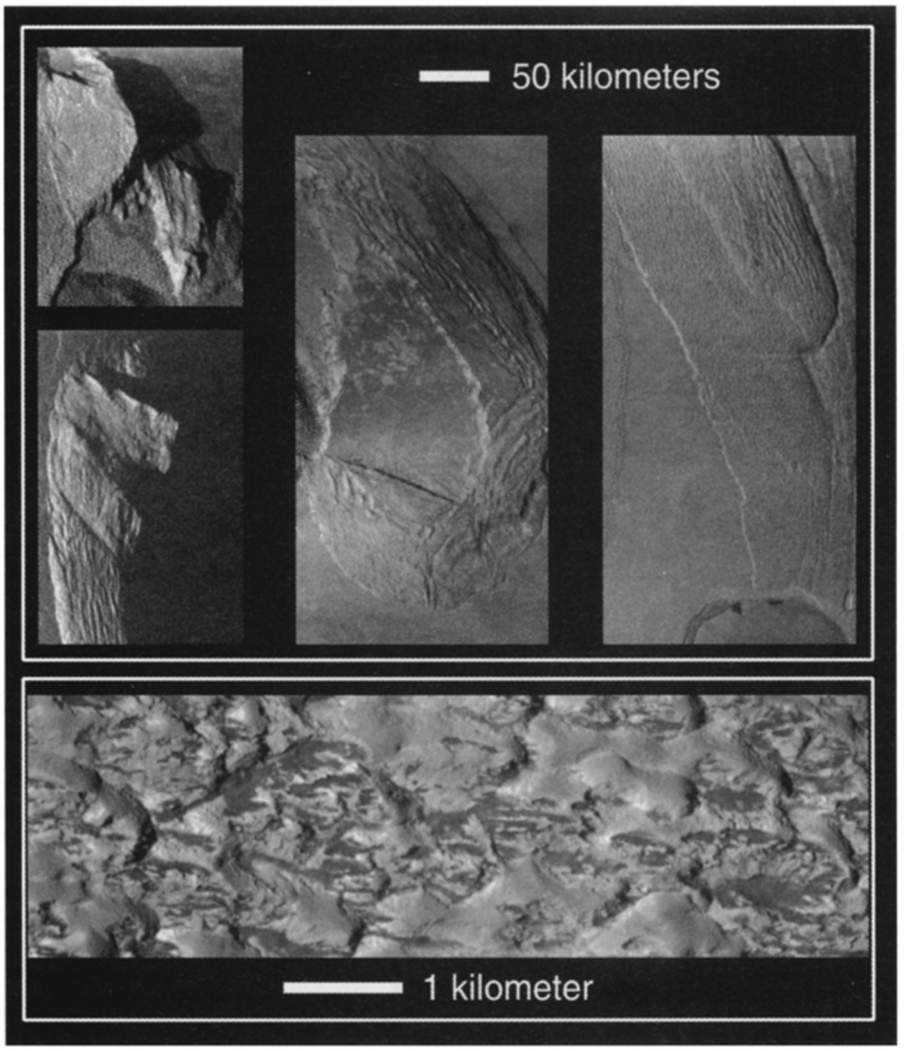
In the December Icarus, McEwen and his colleagues propose that Io harbors a global ocean of molten rock, or magma, beneath its surface. This magma ocean could form mountains by lifting and tilting blocks of crust so that parts stick up. The magma ocean may also hasten the demise of the mountains by increasing the seismic shaking of Io's surface. The shaking could accelerate the mountains' collapse.

On Nov. 25, Galileo traveled through Jupiter's radiation belts once more to take a close-up portrait of Io's south pole. A temporary shut-down, however, prevented the craft from taking the sharpest images possible. Johnson has his fingers crossed that it will survive to take a second—and possibly final—look at Pele, Prometheus, and Loki in February.

That could be the mission's swan song, but astronomers hope Galileo will last until early 2001, when it would have the opportunity, in tandem with the Saturn-bound Cassini craft, to take images of Io.

Already exposed to about twice the cumulative dose of radiation that it was designed to handle, Galileo "is running a little bit beyond its warranty," says Johnson. A grating on the craft's near-infrared spectrometer has become stuck, and the loss of a computer memory cell briefly shut down Galileo just before the Oct. 10 flyby and nearly cancelled the observations.

With luck, however, it won't be time to say goodbye to Galileo until funding runs out, Johnson says. □



Top: Ridges surround four mountains on Io, indicating that gravity is causing material to slide down the sides. Bottom: This close-up of a fifth mountain is one of the sharpest images ever taken of Io, showing details as small as 9 meters across.