Visions of Europa

Galileo tour heightens speculation about life on Jovian moon

By RON COWEN

The signal vanished for agonizing seconds, then came back much clearer, though not appreciably louder.

"...relay this information to Earth.... Using my suit radio—no idea if it has enough range, but it's the only chance. Please listen carefully. THERE IS LIFE ON EUROPA. I repeat: THERE IS LIFE ON EUROPA..."

—Arthur C. Clarke, *2010: Odyssey Two*

This 1982 text is science fiction, but the premise may contain a nugget of truth. It's possible—some researchers now say even plausible—that Jupiter's moon Europa has the two ingredients deemed necessary to sustain primitive life: water and volcanic activity.

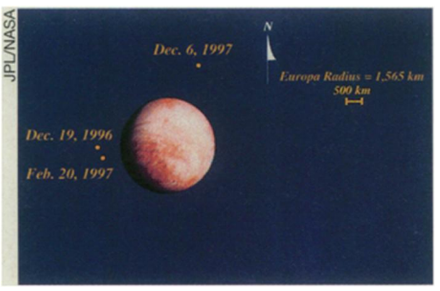
As researchers continue to analyze evidence gathered by the Voyager spacecraft in the late 1970s, they find more and more hints that Europa may harbor an ocean beneath its icy crust. Moreover, a gravitational tug-of-war with Jupiter and two of the giant planet's other large moons, Ganymede and Io, may warm Europa's interior enough to maintain a liquid ocean. The heat may also trigger volcanism.

Although the bone-dry channels that crisscross Mars suggest that water once flowed across the Red Planet, "if we're looking for liquid water and the possibility of life that exists today, the chances of finding them are just as good, or even more so, on Europa," says Torrence V. Johnson of NASA's Jet Propulsion Laboratory in Pasadena, Calif.

As project scientist for the Galileo spacecraft, which began its 2-year tour of Jupiter and its moons last December, Johnson has a special interest in Europa. On June 27, a few hours after a flyby of Ganymede, the craft passed close enough to Europa to photograph its surface at a resolution higher than that possible with the Voyager craft.

Hampered by a broken main antenna, Galileo transmits data extremely slowly. It won't send a Europa image for several more weeks. Europa aficionados will have to wait even longer for Galileo to take its sharpest images. Subsequent passes late this year and early next are expected to bring the craft within 600 kilometers of Europa, revealing surface features that may be as small as 10 meters across.

Although Galileo wasn't designed to search for an ocean and lacks instruments that could peer beneath Europa's icy skin, planetary scientists plan to scrutinize the pictures and other data for indirect signs of a watery reservoir lurking beneath the surface. For example, scientists want to compare the Galileo images with those taken by the Voyager 2 spacecraft, searching for surface changes that might have been caused by water emerging from below. In addition, Galileo may be able to detect a magnetic field, which could be considered evidence of an ocean containing dissolved minerals.



Galileo is scheduled to take extreme close-ups of Europa during three flybys. During Galileo's fourth visit to a Jovian moon, set for Dec. 19, the craft is expected to image equatorial features as small as 20 meters across. Galileo should do even better on Feb. 20, 1997, when it's scheduled to examine details in Europa's midlatitudes down to a resolution of 12 m. On Dec. 6, 1997, the craft is likely to zoom in on the moon's north pole and should resolve structures as small as 11 m.

At the annual Lunar and Planetary Science Conference in Houston last March, Jeffrey S. Kargel of the U.S. Geological Survey in Flagstaff, Ariz., and Guy J. Consolmagno of the Vatican Observatory research group at the University of Arizona in Tucson described three ways that a briny ocean might create a magnetic field on Europa. The simplest model proposed that turbulent motion within a salty ocean generates a magnetic field.

A more complex model, considered more likely by Kargel and Consolmagno, begins with the observation that as Europa orbits Jupiter, it experiences a magnetic field that varies in intensity. This variation would induce electric currents in a salty ocean, which in turn would produce a magnetic field at Europa's surface. Conceivably, that field might be large enough to perturb Jupiter's magnetic field in the vicinity of Europa.

A third scenario assumes that the icy shell is perforated so that the underlying ocean is in electrical contact with the sea of charged particles, or plasma, that whips past the moon. Jupiter's magnetic field generates an electric field in the moving plasma. Because the ocean would complete an electric circuit with the plasma, current would also flow through the water and induce a sizable magnetic field.

Evidence for these models may not be available immediately, says Margaret G. Kivelson of the University of California, Los Angeles and a member of Galileo's magnetometer team. She notes that Galileo must come within a few hundred kilometers of Europa to record a magnetic signal. Such a close approach won't occur until November. Moreover, she adds, the craft can only detect a magnetic field produced by Europa if it's at least 10 percent as strong as Jupiter's.

Neither the Galileo images nor the magnetic data can determine unequivocally whether Europa has an ocean, asserts Steven W. Squyres of Cornell University. Johnson concurs, but he adds that Galileo could serve as a scouting mission for future spacecraft with more appropriate instruments.

If Europa does sport an ocean, Galileo might by sheer luck take a snapshot just as a geyser of water shoots out through the icy surface, says Johnson.

To the naive observer, Europa hardly seems a place to harbor water, let alone play host to some version of primitive life. Lying five times farther away from the sun than Earth does, Europa's surface is a frigid 128 kelvins

(-145°C). Harsh radiation and energetic charged particles flung out by Jupiter's intense magnetic field pelt this Jovian satellite.

Speculation that Europa might possess a subsurface ocean goes back at least 25 years. In 1971, John S. Lewis, now at the University of Arizona, calculated that the interior of a large, frozen moon—such as Europa—should have partly melted because of radioactive decay of material at its core. Such musings were thrown into the spotlight when the Voyager 2 spacecraft flew past Europa in 1979 and revealed that a network of long, sinuous fractures scars its smooth, icy surface. These dark wrinkles bear an uncanny resemblance to cracks that have opened up in sea ice on Earth and then frozen over.

"I always get a kick out of showing geologists a map of Europa," says Johnson. "They want to know which polar region on Earth they're looking at."

The watery explanation for the cracking goes like this: If Europa's icy shell floats above a layer of water, the shell would rotate at a different rate than the main body of the moon. The combined stress produced by this differential rotation and Jupiter's gravitational tug would flex the icy surface in such a way as to produce cracks. Water seeping up between the cracks would darken the fractures, accounting for the dark wrinkles.

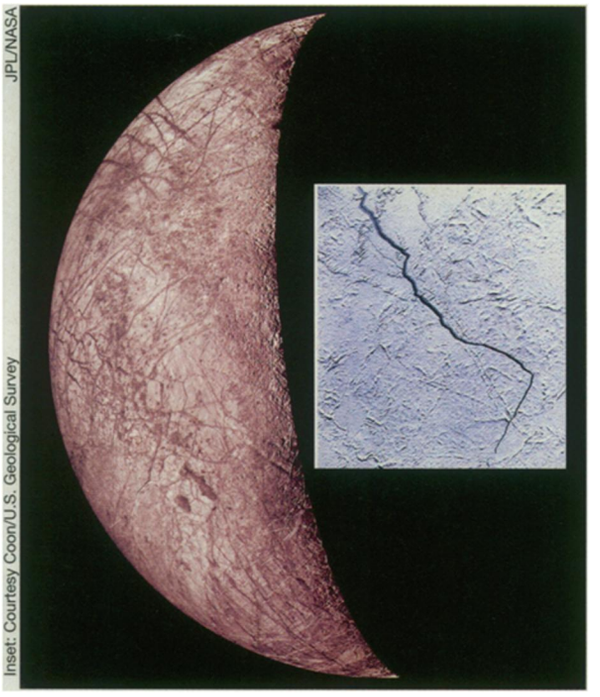
In at least one region on Europa, the facade betrays further hints of a hidden ocean. Near the center of the hemisphere that always faces away from Jupiter, dark wedges bedizen the icy surface, separating what appear to be floating blocks of ice. As in terrestrial sea ice, the wedges seem to form along preexisting cracks and may represent a widening of these cracks. Moreover, the blocks of ice appear to have moved or rotated, as if they were floating on water, according to a 1989 study by Paul Schenk, now at the Lunar and Planetary Institute in Houston, and William B. McKinnon of Washington University in St. Louis.

In a new study, scheduled to appear in the October ICARUS, Robert T. Pappalardo of Brown University in Providence, R.I., and Robert J. Sullivan of Arizona State University in Tempe extend that work, suggesting that cracks may cover more than the region studied by Schenk and McKinnon.

At the Lunar and Planetary Science Conference, Pappalardo and Max D. Coon of the Northwest Research Associates in Bellevue, Wash., proposed that the same kind of process that shapes centimeter-thin, floating blocks of ice on Earth might also shape ice plates several kilometers thick on Europa.

Nonetheless, Europa's fractured appearance doesn't necessarily imply that an ocean exists on the moon today. An ocean that existed sometime in the past could have sculpted the surface features but may now be entirely frozen. Alternatively, a layer of warmer ice underlying the frozen surface might also account for the cracks and wedges.

Two other lines of evidence, however, support the notion of recent aquatic activity on Europa. This moon, overall, appears unusually bright, perhaps because water has risen up from beneath the icy crust and rained down as a fresh layer of snow. In addition, the Voyager images show that relatively few craters have marred Europa's surface. Yet the battered faces of Europa's icy sisters, Ganymede and Callisto, bear witness to heavy bombardment by asteroids and comets. The Voyager data suggest that Europa got a facelift as recently as 10 million years ago. Water flooding and freezing over the moon's surface could have resculpted it.



Dark bands that scar the surface of Europa in this colorized mosaic of images taken by the Voyager 2 spacecraft hint that an ocean lurks beneath the icy skin of this Jovian moon. Inset: On Earth, the relative motion of ice plates floating in the Arctic Ocean causes plates to open along preexisting cracks. Seawater fills the openings and freezes quickly, creating dark, sinuous features like this one. Although this structure is only about 50 meters wide, it resembles Europa's 25-kilometer-wide dark bands, which may have a similar origin.

What does a chilly reservoir of water, probably buried under several kilometers of ice, have to do with life? Not much, says geologist John R. Delaney of the University of Washington in Seattle, unless it's accompanied by volcanism.

In 1991, researchers in the undersea vessel *Alvin* discovered that recent underwater eruptions had destroyed native marine life in a seafloor region off the coast of southern Mexico. Yet a new layer of bacteria had already blanketed the region. *Alvin* showed that such organisms cluster near hydrothermal vents, places where seawater seeps into Earth's crust, heats up, and reemerges as a jet full of minerals, carbon-based compounds, and other materials that support life (SN: 10/22/94, p. 260).

In more recent seafloor studies, researchers found that a watery environment agitated by volcanic activity can sustain primitive bacteria that live far removed from sunlight (SN: 10/21/95, p. 263). For bacteria that make their home in undersea rock, volcanism serves two purposes, Delaney explains. In addition to dredging up fresh supplies of vital minerals, it speeds them through the water to the immobile organisms.

Applying this terrestrial lesson to Europa begs the $64,000 question: Is the moon volcanically active beneath its icy shell? The Voyager craft shocked scientists when it discovered widespread volcanism on Jupiter's moon Io. That moon, which lies closer to the giant planet than Europa does, remains the only one in the solar system known to have such activity.

Tidal heating, generated as Jupiter's gravity flexes Io back and forth, powers that moon's eruptions. The same process may produce enough calories to keep liquid any ocean on Europa. But the heat may not suffice to melt rock and trigger volcanic eruptions in that ocean, says Squyres. Moreover, he adds, Galileo lacks the equipment to discover volcanism on Europa.

Assuming that the Galileo data show evidence of water, Squyres already has ideas for future missions. In principle, a craft equipped with long-wavelength radar could see through the ice and detect an ocean, he says. A laser-ranging device, which measures the shape of a planetary body, could determine the amount of flexing experienced by Europa during each orbit around Jupiter. The change in shape could indicate whether or not the moon has a watery base.

Ultimately, of course, if an ocean exists, "you want to get into it, taste it, figure out if it harbors life," says Squyres.

"It would be great to have a seafloor instrument like *Alvin* land on Europa," says Johnson. "That may sound like science fiction, but we do it routinely in remote regions on Earth." □