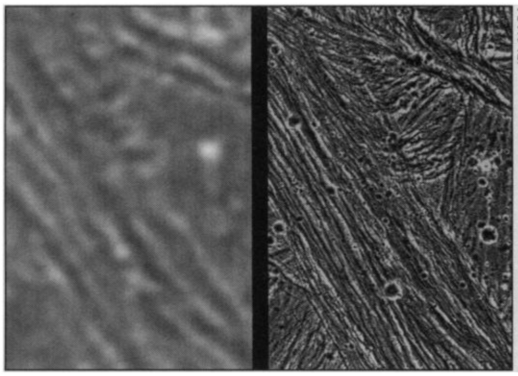
PLANETARY SCIENCE

Galileo Finds Mysterious Magnetic Field at Ganymede



JPL/NASA

A sharper image. Voyager's images *(left)* offered a first glimpse of Ganymede's scarred surface, but Galileo got a closer look *(right)*.

When planetary scientists got their first good look at the surface of Jupiter's largest moon, Ganymede, back in 1979, the images sent back by two Voyager spacecraft suggested that turmoil deep within the icy moon had torn its surface asunder and flooded it with lavas of ice. The Voyagers' view suggested that this turbulent era ended several billion years ago. But first impressions of planetary bodies, like those of people, can be deceptive.

Last week, scientists announced that a closer look at Ganymede by the Galileo spacecraft reveals that even now, the moon's calm and icy surface conceals a hot and turbulent interior. Indeed, in addition to gathering dramatic images 20 times sharper than the Voyagers', Galileo recorded clear signs of a magnetic field—the hallmark of an internally active body whose interior is melted and churned by a deep heat source. This startling discovery accompanies the less surprising recognition of a field at Jupiter's moon Io, long known to be in geologic upheaval (see Report on p. 337).

The news is forcing researchers to consider what kind of midlife infusion of heat energy might have rejuvenated Ganymede's magnetic field and perhaps its geologic activity. For now, scientists are at a loss to explain it. "The evidence seems quite unambiguous that Ganymede does generate a magnetic field," says Margaret Kivelson of the University of California, Los Angeles, who led the magnetometer team. "And we are as puzzled as anyone over what could produce it."

Theory may be in a shambles, but the observations are clear-cut. As Galileo swept within 835 kilometers of the 5262-kilometer moon, the strength of the field recorded by the magnetometer rose to five times the level of the Jovian field in that vicinity, and its orientation swung around to point at the moon. At the same time, Galileo's plasma wave receiver, operated by Donald Gurnett of the University of Iowa and his team, began to detect the distinctive emissions of charged particles trapped inside a magnetic field. All this seems to require that Ganymede is generating its own magnetic field. "It's surprising, no doubt about it," says planetary physicist David Stevenson of the California Institute of Technology. "If I had been asked a week ago if Ganymede would have a magnetic field, I would have said it was unlikely."

The reason was a presumed dearth of heat inside Ganymede, which is a ball of rock about the size of Earth's moon covered by 1000 kilometers of water ice. On such bodies, magnetic fields are generated by geodynamos consisting of a conducting liquid circulating within the planet or moon. Heat is needed both to melt some part of the interior and to churn the liquid. Ganymede does harbor an internal heat source—the slow decay of radioactive elements in its rock. But the moon formed 4.5 billion years ago, and researchers had assumed that any lingering heat resources were too modest to run a dynamo and produce a magnetic field today.

After hearing the Galileo results announced at the 10 July press conference, planetary scientist William McKinnon of Washington University in St. Louis did a preliminary calculation of just how much heat Ganymede might have. He converted his computer model of radiogenic heat generation and loss in Pluto, another rock-and-ice body, into one of Ganymede. He found that the heat released from the presumed rock mass at the moon's center would indeed be sufficient to extract iron from the rock, forming a molten core that could persist until today.

Still, researchers are puzzled. "It's likely Ganymede has a metallic core," concedes Stevenson, "but would you get a magnetic field?" He believes that the numbers suggest that Ganymede would have only a small core, whose heat would be too weak to churn it into a dynamo. Instead, the heat would simply conduct away from a stagnant core.

Another option is that the heat melted part of the ice, forming an ice-covered ocean whose stirrings created a dynamo. But because even salty water is far less conductive than metal, the ocean would have to circulate very rapidly, perhaps 10 centimeters per second compared to the millimeter per second of Earth's metallic core. And it seems unlikely that the small amount of heat thought to be still trickling out of Ganymede could churn a water ocean that fast, says Stevenson.

These apparent difficulties are pushing Stevenson and others to think about how else the moon might have been warmed. As it happens, geologists have been wrestling with a similar conundrum for more than a decade. Their problem was the obvious surficial difference between Ganymede and its near-twin Callisto. While Callisto is covered by a dark terrain apparently unchanged since about 4 billion years ago, the Voyagers showed that about half of Ganymede is covered by a bright terrain that seems to have been stretched, fractured, and flooded by "volcanic" ice lavas perhaps a billion years after the dark terrain formed. Such deformation and volcanism requires heat, yet geologists reasoned that the radiogenic heat sources of the two moons should be similar. Where did Ganymede get its extra heat?

One possible source is Jupiter. Even today, the volcanoes on Jupiter's moon Io are being driven by the planet's rhythmic gravitational massaging of that moon. This tidal flexing of Io's interior and the resulting heating occur because Io is forced into an elliptical orbit by gravitational nudgings shared among it and other moons. In the present orbital arrangement, Jupiter doesn't heat Ganymede much. But orbital dynamicists Renu Malhotra of the Lunar and Planetary Institute in Houston and William Tittemore of Hanover, New Hampshire, independently proposed more than 5 years ago that as Ganymede's orbit evolved, other moons temporarily distorted it into an ellipse, which would have allowed Jupiter to heat Ganymede. But because the researchers were seeking an explanation for the moon's ancient resurfacing, they had presumed that the tidal effects occurred 3 billion years ago—too long ago to leave enough residual heat to create a magnetic field today.

"Perhaps we have the wrong view of Ganymede," Stevenson now says. "Maybe it has been active more recently than most people had thought, perhaps because of some tidal [effects] in the last billion years or so." Pinning down the timing of Ganymede's turbulent era is now up to the planetary geologists. The exquisite detail of Galileo's images is already upsetting Voyager-based analyses of the order of resurfacing events and inferences about the amount of crustal stretching, says Galileo team member James Head of Brown University. And with only 10% of the data from this encounter downloaded and three more encounters coming up, researchers will soon get a long, hard look at this enigmatic Jovian moon.

–Richard A. Kerr