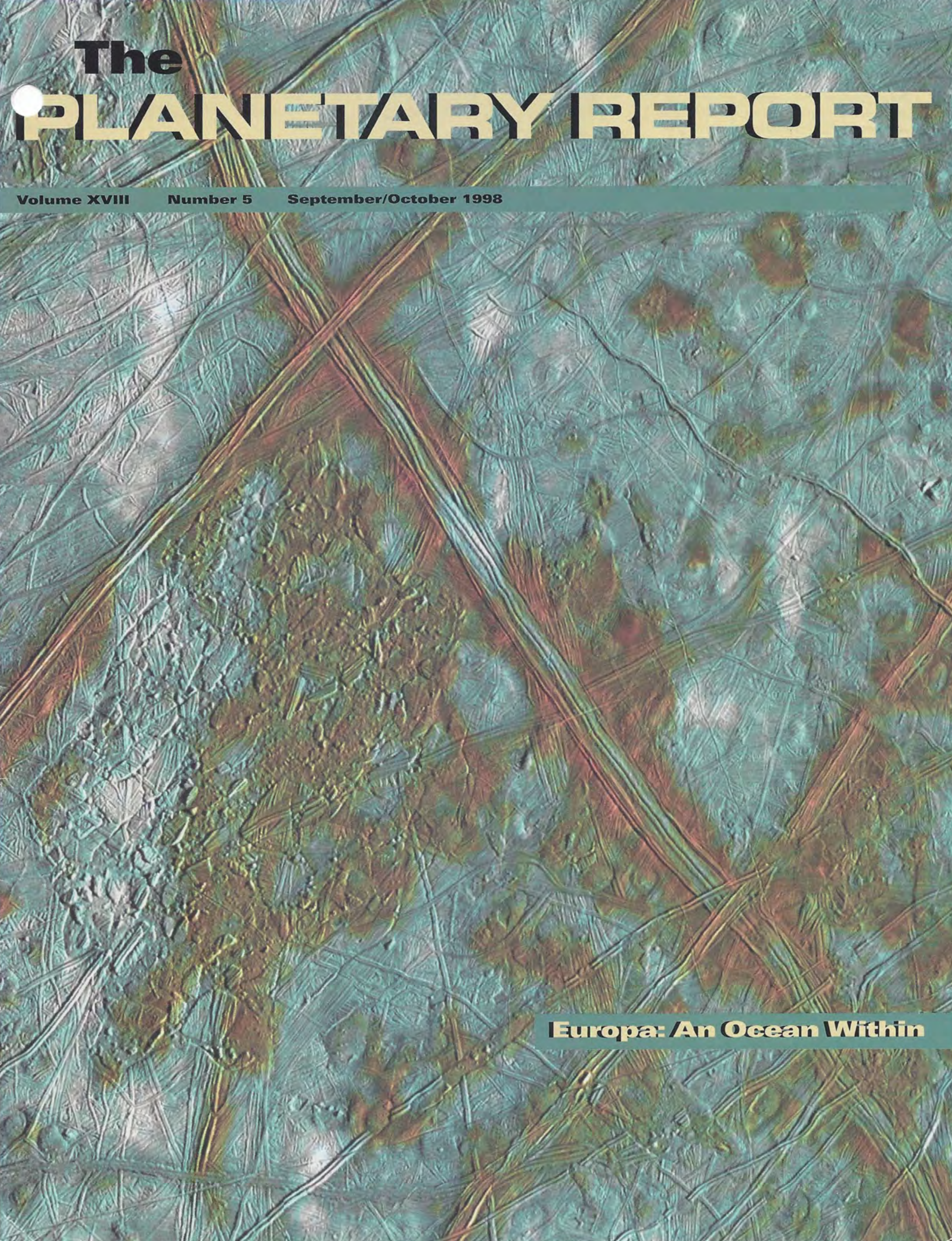
The PLANETARY REPORT

Volume XVIII Number 5 September/October 1998



Europa: An Ocean Within

On the Cover:

What sort of world is this? It's certainly one of the most tantalizing, bizarre, and beautiful worlds yet visited by spacecraft. And it is perhaps the richest in possibility. This is Europa, the world in our solar system most likely to harbor extraterrestrial life. We see it here in an enhanced-color image created from data gathered during three flybys. The colors, although exaggerated, do reflect the actual colors of Europa. The blue corresponds to icy plains, which are among the oldest features on this moon. The reddish areas show where the water ice has been mixed with materials extruded from below. Bright white areas are ejecta rays of material blasted out by the impact that formed the crater Pwyll, which lies 1,000 kilometers (600 miles) to the south. These markings, superimposed on other features, are the youngest features visible in this region.

Image: JPL/NASA

From The Editor

I admit it. I am a Europa partisan. I have been since 1979, when *Voyager 1* first showed us the bright, cracked, deeply alien face of this moon of Jupiter. Almost immediately people began speculating about what could make a moon look like that—is there an ocean underlying the ice crust? And if there is water, could there be life?

Now, nearly 20 years later, there is a spacecraft again exploring that moon. *Galileo* was designed to investigate the entire Jovian system, but last year when its primary mission was finished, the probe was redirected to study Europa in detail.

Every new swingby adds to the evidence that there is an ocean on a world other than Earth. I don't understand why everyone isn't enraptured by the possibilities of that little world.

So, in this issue, we once again bring you Europa. And I hope you'll agree that it is a completely enthralling world. (Of course, there are some who can't imagine anything more thrilling than Mars . . .) As you look at the Europan surface, consider that Gene Shoemaker used to say that we are more likely to find life beneath that ice than on any other alien world in our solar system, including Mars.

—Charlene M. Anderson

Note: The Stuff of Life is on summer vacation but will return in our next issue.

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Members' **Dialogue**

A Major Loss

In News and Reviews (see the May/June 1998 issue of *The Planetary Report*) Clark Chapman noted that "Australia recently closed down its small, but significant, telescopic program of searching for NEOs (Near-Earth Objects)."

In 1996, our last year, we found just six of the 50 near-Earth asteroids discovered. In earlier years we found more, whilst the American search programs discovered less, making for a larger [Australian] fraction. If we were still searching in the same way in 1998, our contribution would be proportionally smaller because of the wonderful productivity of [other] searches.

The most significant outcome of the Australian effort, however, was in follow-up rather than discovery. If you find a NEO but do not secure its orbit with follow-up astrometry, it's like finding the needle in a haystack and then tossing it back again. As the only southern hemisphere NEO tracking program, we had a special responsibility in this regard, and much sky to cover. In the last few years of operation, we delivered about 30 percent of all NEO astrometry derived worldwide and 60 percent of all precoveries (detections of pre-discovery images on photographic plates). Those are not "small" contributions.

The real impact of the cessation of Australia's NEO program will not be felt for another year or two. This will be when NEOs discovered in the north start to reappear in the southern sky, but there is nobody to recover them except an amateur astronomer or two.

—DUNCAN STEEL,
Adelaide, South Australia

Earth and Space

I have just finished reading "The Green Space Project" by Kim Stanley Robinson in the May/June 1998 issue. I was thrilled to read an article by someone who shares my two passions: space and the environment. As he stated, the two are not mutually exclusive. To the contrary, the two are necessary to the continuing development of each other.

I think space advocates who are also environmentalists share a sense of something more than ourselves and the limited human world—something larger, less confined and constricted. It is a connection to Earth and the universe, a view both practical and wondrous.

—MARILYN FADEL,
Clearwater, Florida

The Search for Life

As a non-scientist, I'm amazed to see what is written by many scientists when discussing the search for life in the universe. The latest example is the article by Bruce Jakosky in the July/August 1998 issue. These statements illustrate my point: "Finding proof that life is not unique to the Earth would crystallize our view of humanity's place in the galaxy: it would mean we are just another result of especially interesting chemistry." Is he saying that finding no life elsewhere confirms the Adam and Eve fable?

He then states that "If there has never been Martian life, we would have to question seriously our current views of the origin of life on Earth and the possibility of widespread life in the universe." How does this follow? A lack of evidence for life on Mars is irrelevant to the possibility of life in galaxies a billion light-years from here.

The obsession that some of the scientific community has with searching for life in the universe actually impedes the manageable goal of simple exploration that we should have. That process will find life in due course.

—PAUL H. KLAVERKAMP,
Lake Shore, Minnesota

I agree with much of what Bruce Jakosky says in "Searching for Life in the Universe" in the July/August 1998 issue of *The Planetary Report*, but he errs when he states that "Finding even simple microbes on another planet would tell us that life has originated somewhere independently of life on Earth." It cannot be assumed, without proof, that any extraterrestrial life that might be found is independent in origin from our own. Proof would require comparison of the genetic material of the other life with ours. For terrestrial life, this material consists of DNA and RNA.

If extraterrestrial life is ever found, the first question will be: what is the nature of its genetic material? Only if that is fundamentally different from ours will it be possible, in the present state of our knowledge, to conclude that the other life is not a branch of our own.

—NORMAN HOROWITZ,
Pasadena, California

For me, the most important reason to search for extraterrestrial life is that we would discover how life evolved in a different way. That would tell us a great deal about evolution and, possibly, about what life really is.

—JANE SETLOW,
Upton, New York

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Alan Shepard, the first American to reach space, died July 22. History will remember him, and his Soviet counterpart Yuri Gagarin, as heroes who dared take the first bold steps off our home world and into humanity's future.

Shepard was able to follow his first, 15-minute sub-orbital flight with a journey to the Moon, the ultimate goal set by John F. Kennedy when he issued the challenge to send a man to that one-time paragon of the unattainable. While Shepard brought a sense of honor and pride in achievement to that task, he also brought a sense of fun. Obituary writers around the world, even as they lauded his achievements, remembered that it was Alan Shepard who dared play golf on the Moon.

He died while we were preparing this issue, and fortuitously we had planned to use Alan Bean's painting of Shepard's lunar golf game to illustrate this essay. It is now doubly appropriate. What a way to be remembered—as a man who achieved the unachievable and had fun while doing it. —Charlene M. Anderson, Associate Director

Striving Outward

Opinion by James D. Burke

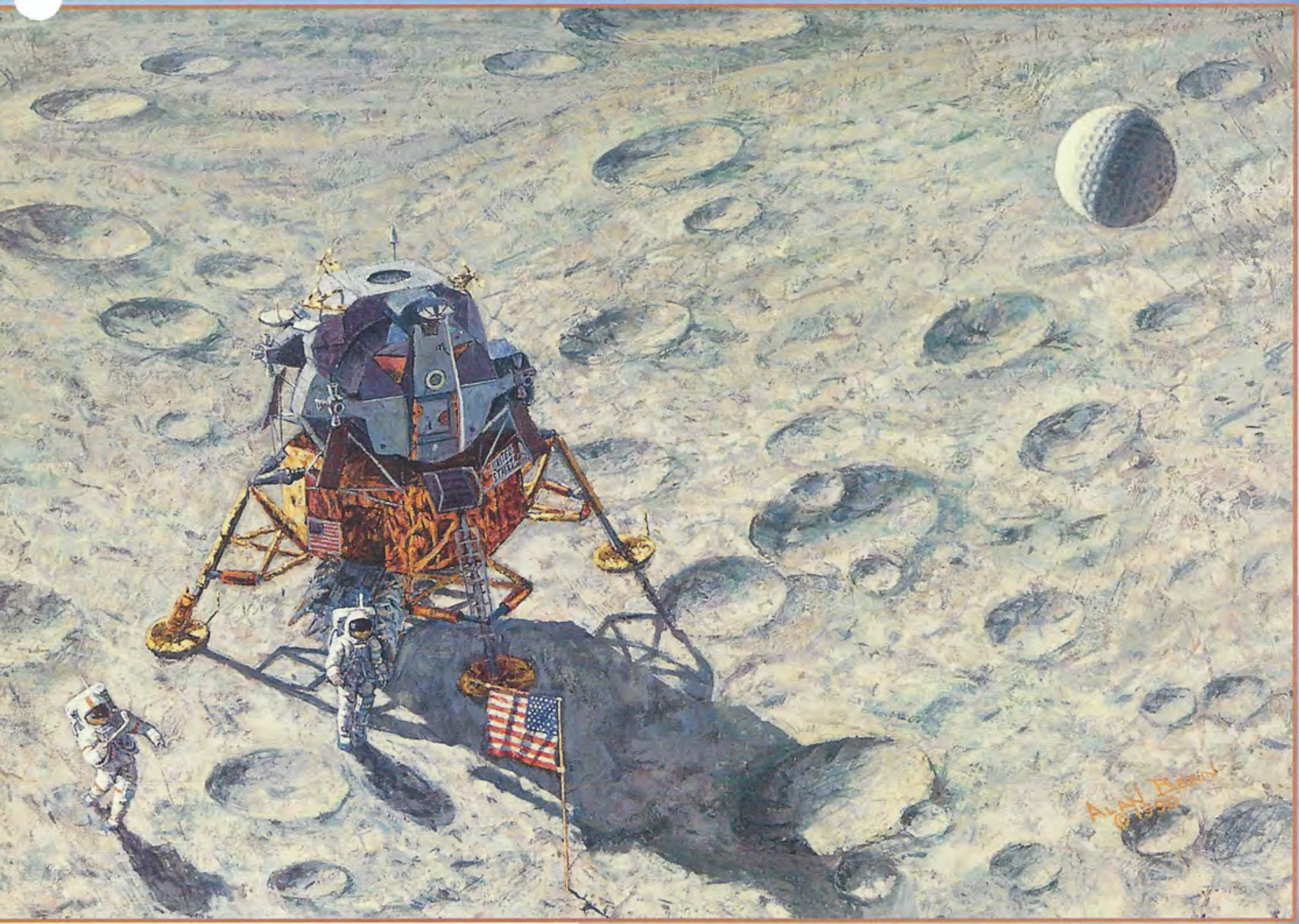
In every age and in every place where humans have left records, we see evidence of a marvelous instinct. As soon as societies obtain by their labors even a little product beyond the needs of bare survival, they begin to create arts, to invent gods, to wonder and theorize about the universe. The line of descent from ancient legends to the modern quests of philosophy, religion, and science is direct and unequivocal. It is a constant of humanity to reach toward the future, to want to visit the stars, to want to know itself. It seems that this drive is just something contained in the human mind—or, if you wish, placed by a Creator in the fabric of spacetime where that mind resides.

At times it may seem that we have lost this exploratory urge, but always it returns, reshaped by current events. Why is it that we strive to understand our place in the heavens and seek other intelligences out there?

Yes, the cosmos is calling. But how do we sophisticated humans reply? Why not spend all our energies, skills, and resources on maintaining our beautiful home planet, relieving misery, educating each other, improving our civic behavior? Many answers are offered, but none is universally accepted. In the United States, the debate takes a peculiarly mercantile form because of the pernicious idea that unless something can show a profit it is not worth doing. Yet even at its most vulgar, America remains a fountainhead of the arts and sciences. The same is true in other parts of the world, including many places whose living standard is relatively low but whose people share dreams of a wider future. Governments, however, are sometimes unresponsive to this fundamental human urge. In trying to respond to short-term crises, they lose sight of the deeper purposes of a civilization.

Fifteen years ago the enterprise of deep-space exploration was foundering. The American *Apollo* program had won the Moon race, and the failure of its Soviet competitor caused both manned lunar programs to collapse. Robotic lunar and planetary exploration, also an emblem of peaceful, competitive achievement by both societies during the Cold War, was dragged down, too, despite a string of remarkable achievements by both sides.

The Planetary Society was founded to remedy that situation. In 1980 our founders, Carl Sagan, Bruce Murray, and Louis Friedman, had a clear reason for launching the Society. They believed that people were ahead of their governments in realizing the long-term importance of reaching out into the starry void. Events soon proved them right. The Society grew explosively. Only three years after its founding, it was the world's largest space-advocacy organization. And the



Society answers to its members in a particular way. We try to share with them not only the facts about humanity's drive to explore the Sun's realm, find planets of other stars, and seek other intelligences in the cosmos but also the wonder, the mystery, and the fun of responding to that drive.

Fun? At the taxpayers' expense? Yes. Fun and creativity are so closely linked in the human character as to be parts of the same behavior, and creativity is what changes the world. We deep-space explorers know that it is right for us to go on striving outward. We cannot articulate reasons that will satisfy everyone, and we do not know what we shall find. But we do know that we are part of some natural process, life seeking self-knowledge, life seeking other life.

The Planetary Society gives us one way to express this ancient human impulse. We shall continue.

James D. Burke is Technical Editor of The Planetary Report.

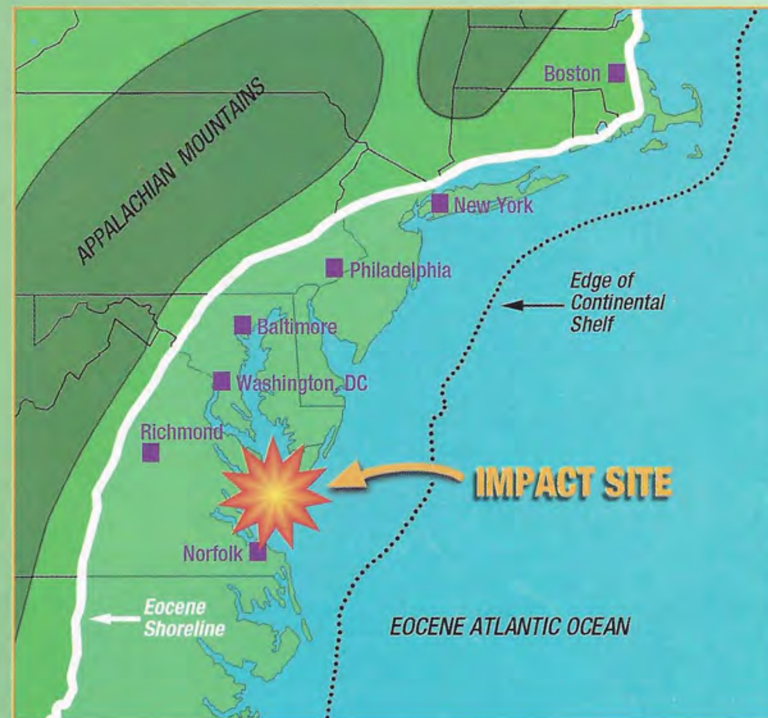
As Apollo 14 astronauts Alan Shepard and Edgar Mitchell were winding up their second Moon walk, Al turned toward the television camera. "Houston, you might recognize what I have in my right hand as the handle for the contingency return sample. It just so happens to have a genuine six iron attached to the end. In my left hand, I have two little white pellets that are familiar to millions of Americans. I drop one down in front of me." Al faced the ball and began a modified backswing. "Unfortunately, the suit is so stiff, I can't do this with two hands, but I'm going to try a little sand trap shot here."

With the Apollo space suit, a smooth arm and hand motion is impossible, and Al just topped the ball. It rolled into a small crater a few yards away. Ed observed, "Hey, you got more dirt than ball that time." As the whole world watched on television, Al dropped the second ball, said "Well, here we go again," and took his best swing. Dirt and dust flew, the ball disappeared, and Al exclaimed, "Miles and miles and miles."

As Al would say later, "The fun with the golf shot certainly had to be the greatest thrill. It was a one-handed shot and I wasn't able to make a very big turn on the backswing. But due to the conditions there, the ball ended up traveling 200 yards and probably had a flight time of 15 seconds."

Painting, In Flight, *and caption by Alan Bean, astronaut,* Apollo 12

Backyard Bolides: Finding a Buried Impact Crater



by C. Wylie Poag

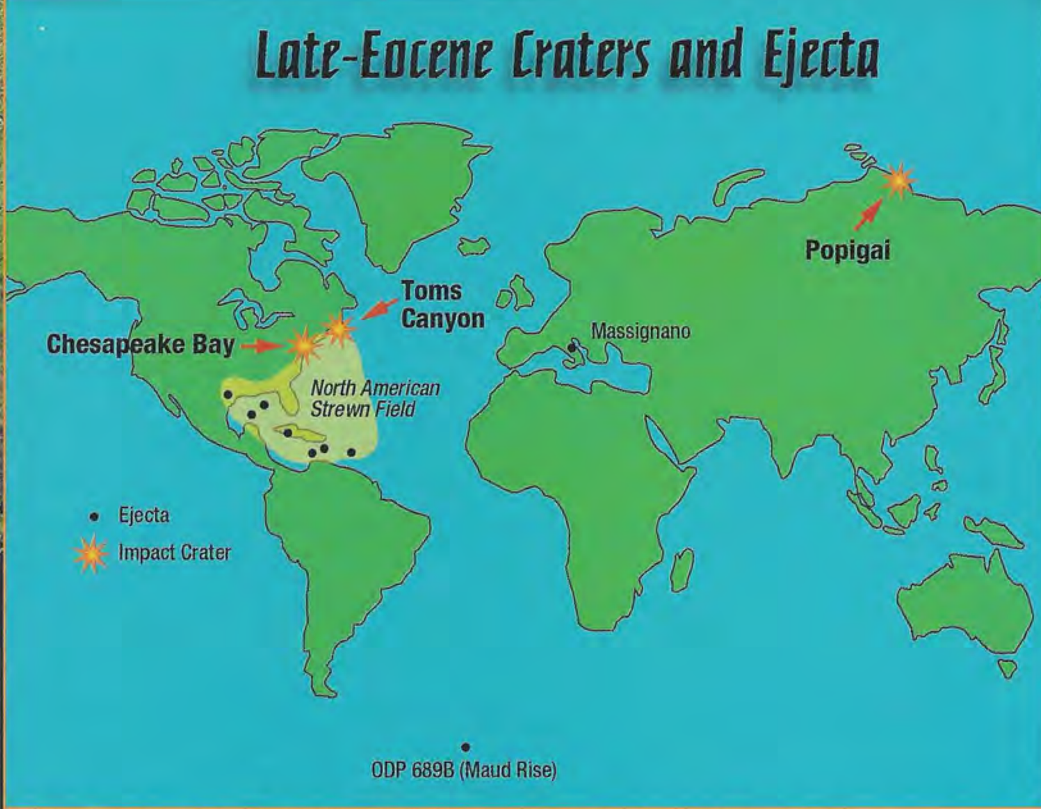
Giant impact craters don't show up in your own backyard every day. But that's essentially what happened to me. In the course of assessing the geological framework of the US Atlantic continental margin, I virtually stumbled across the Chesapeake Bay impact crater.

An interest in impacts came late in my career. Early on, I spent seven years exploring for oil and gas with Chevron Oil Company, and then I taught geological oceanography at Texas A&M for four years. I went to work for the US Geological Survey (USGS) in 1974. My specialty is reconstructing the geological history of continental margins from microfossils and seismic reflection surveys. Microfossils, as you might expect, are tiny shells produced by microscopic organisms. Seismic reflection surveys use sound waves to image subsea geological structure. In a sense, the way geologists image the Earth's interior is similar to the way physicians use sonograms to image a fetus.

My research direction changed in 1983, when I had the opportunity to serve as Co-Chief Scientist on the National Science Foundation's drilling ship *Glomar-Challenger*. With an international party of marine scientists, we set out to drill a series of deep coreholes into the seabed 140 kilometers (90 miles) east of Atlantic City, New Jersey. The key corehole was at site 612, located in 1,400 meters of water near the edge of the continental shelf. That is where we turned up a thin layer of impact ejecta, including microtektites, microkrystites, shocked quartz, stishovite, and coesite. These unusual components were diagnostic evidence that a bolide (large comet or asteroid) had struck within 250 to 500 kilometers (150 to 300 miles) of the drill site.

A combination of microfossils in the ejecta layer, plus a radiometric date from the impact glass, pinned down the time of the impact at approximately 35 million years ago, in the late-Eocene epoch of geological time. We found microfossils from different geologic ages mixed together in the ejecta layer; presumably these were scrambled by the impact shock.

Given the evidence of an impact, I had to wonder: was the source crater buried nearby under the continental shelf? The USGS had been imaging the subsea geological structure of the Atlantic continental shelf with seismic reflection surveys for about 10 years, and we had never identified an impact crater in that region. However, no one in our Woods Hole group was a crater expert, so we probably wouldn't have recognized one if we had imaged it. I decided to scrutinize our seismic archives again.



Far left: The coastline of North America looked very different 35 million years ago when an object from space struck offshore, at a location now part of Chesapeake Bay.

Left: A view from space reveals no surface evidence of the late-Eocene impact. Sediment buried all signs of the crater, which geologists discovered using sound waves to build a picture of the subsea geologic structure.

Above: Geologists have since found other craters of about the same age around the world, strengthening the case that a comet shower devastated Earth, causing major extinctions.

Maps: courtesy of C. Wylie Poag; redrawn by B. S. Smith. Image: US Geological Survey

A Crater Beneath the Bay

While I was engaged in this search, colleagues from the USGS and the Virginia State Water Control Board (Bob Mixon, Dave Powars, and Scott Bruce) turned up impact ejecta in four coreholes drilled on the east and west margins of Chesapeake Bay. They didn't realize at first that the cores contained ejecta; they were interested in the general composition and age of the subsurface deposits and in the nature of aquifers. Finding an unusual mixture of older rock fragments in the cores, they asked me to analyze the microfossils in the mixture to determine its geologic age. I was surprised to see in these Virginia cores the same group of microfossils that we had seen in the ejecta from site 612 off New Jersey. The microfossil similarity caused me to suspect a connection between the onshore and offshore deposits. Were the Virginia cores also impact ejecta? To make sure, I sent samples to Christian Koeberl, a geochemist at the University of Vienna, who confirmed the presence of impact-shocked minerals.

The clincher came when Texaco, Inc. released seismic reflection profiles that their geologists had collected in Chesapeake Bay. The seismic data blew our minds! There in the middle of the bay, buried by 350 meters of sediments, was a gigantic hole, 80 kilometers wide and almost a kilometer deep (50 miles wide, 0.5 miles deep). By chance, two of the coreholes had penetrated the impact breccia (fragmented rock) that fills the crater. The other two were drilled just outside the crater rim and sampled the surrounding ejecta blanket. How's that for beginner's luck!

The microfossil evidence told us that the crater was approximately 35 million years old, the same age as the site 612 ejecta. Koeberl later compared the geochemistry of the two ejecta deposits and concluded that the Chesapeake Bay crater probably was the source of the site 612 ejecta. Moreover, it appears that the Chesapeake Bay crater was the source for a widespread deposit of impact debris known as the North American tektite strewn field. The strewn field covers about 8 million square kilometers (3 million square miles) of the western Atlantic Ocean, Gulf of Mexico, and Caribbean Sea and parts of Texas and Georgia as well. Recently, Bill Glass, a tektite specialist at the University of Delaware, has found probable Chesapeake Bay ejecta in deep-sea cores as far south as the Antarctic.

Other Late-Eocene Craters

In further analyses of the seismic reflection data, I identified 14 small secondary craters (diameter 0.4 to 0.5 kilometers, or 0.25 to 0.30 miles) within 60 kilometers (35 miles) of the primary Chesapeake Bay crater. Secondary craters are caused by the impacts of huge intact blocks of rock tossed out of the main crater. I also identified an intermediate-size primary crater (diameter 19 kilometers, or 12 miles), called the Toms Canyon crater, only 24 kilometers (15 miles) from site 612. The Toms Canyon crater is identical in age to the Chesapeake Bay crater and contains a similar assemblage of mixed microfossils in the crater fill. Though relatively small, the Toms Canyon crater is too large and too far away (300 kilometers, or 180 miles) to be considered a

Popigai crater in northern Siberia is an 85-kilometer-wide (50-mile) scar made 35 million years ago. Geologists have discovered material near Massignano, Italy that may have been ejected by this impact. Image: US Geological Survey

secondary crater to Chesapeake Bay.

Finding two late-Eocene impacts is quite exciting, but we now know there were at least three. While the Chesapeake Bay and Toms Canyon bolides bombarded the western Atlantic, another body struck land in northern Siberia, near the town of Popigai. Radiometric dating gives the Popigai crater the same age as the Chesapeake Bay and Toms Canyon craters. Like the Chesapeake Bay crater, Popigai is 85 kilometers (50 miles) in diameter.

Another important deposit of late-Eocene impact ejecta has been found in Italy. At an outcrop near the town of Massignano, researchers have identified a thin layer containing shocked minerals and a higher than normal concentration of iridium, both of which are impact indicators. The ejecta also contain an unusual assemblage of tiny spinel crystals that are enriched in nickel, additional evidence of a bolide impact. The geochemistry of the Massignano ejecta, however, does not match that of the Chesapeake Bay ejecta, so there is a strong suspicion that the Massignano material may have come from Popigai. Research is under way to determine whether such a connection is plausible.

Recently, geochemical evidence has given rise to speculation that there may be additional sources for late-Eocene impact ejecta. K. A. Farley and colleagues have identified a sharp increase in the concentration of extraterrestrial helium (helium-3) in the Massignano ejecta layer. The helium-3 enhancement lasted for about 2 million years, until the end of the Eocene. Farley interprets the extra helium-3 as evidence that Earth encountered a comet shower approximately 35 million years ago, which would suggest that the Chesapeake Bay, Popigai, and Toms Canyon craters were excavated by the shower (see "Cosmic Dust," page 9).

Effects of a Comet Shower

According to most computer-driven impact models, such a comet barrage should have severely disrupted the late-Eocene biosphere and caused mass extinction of terrestrial and marine organisms. Though a few minor perturbations have been noted, no convincing cases of extinction have come to light so far. Rather, it appears the late-Eocene impacts occurred *between* two major extinction events—one 37 million years ago (the end of the middle Eocene) and the other 32 million years ago (in the early Oligocene epoch).

What are we to make of this apparent contradiction? Perhaps the multiple late-Eocene impacts caused an environmental response not accounted for by current hypotheses. A 2 million year pulse of atmospheric warming may be the answer.

Evidence for a warm pulse comes from several sources: from the ratio of different oxygen isotopes in the shells of late-Eocene marine organisms, from the migration of late-Eocene marine microorganisms from low to high latitudes (implying warmer polar regions), and from the late-Eocene expansion of warmth-loving terrestrial plant and animal populations. The inferred warm pulse started approximately 35 million years ago (at the time of the Chesapeake, Toms Canyon, and Popigai impacts) and lasted until the end of the Eocene (coinciding with the 2 million years of helium-3 influx). It is not unreasonable to speculate that the warm pulse delayed major extinctions until the beginning of the Oligocene 32 million years ago. The Oligocene extinction event has been attributed to global cooling evidenced by a buildup of ice in Antarctica, which might have taken place sooner if not for the heat pulse.

If the comet shower/heat pulse scenario proves to be correct, it would be no surprise to find additional late-Eocene craters. Perhaps there is one in your backyard.

C. Wylie Poag is a Senior Marine Geologist at the USGS, Woods Hole, Massachusetts.

Cosmic Dust: Evidence of a Comet Shower

by Kenneth A. Farley

A sky filled with comets might be a beautiful sight, but it could signal devastation for any life forms unlucky enough to experience one. Evidence is building that a comet shower may have triggered mass extinctions during the late Eocene.

Illustration: Michael Carroll

I never thought about cosmic dust prior to 1994. Up to that time my scientific research had focused almost exclusively on the chemistry of the Earth's interior. But then circumstances led me to analyze the helium contained in a very old sediment, and I found to my surprise that it was highly enriched in the isotope helium-3, indicating that the sediment contained dust of extraterrestrial origin.

Scientists have known for years that helium-3 is a component of cosmic dust, the fine-grained debris that our planet picks up in its travels through the solar system. The surprise was that the helium-3 had survived in the sediment for so long. Helium diffuses rapidly from most minerals, so there had been a general assumption that the tiny particles that make up cosmic dust would not retain helium over geologic time. My measurement proved that helium-3 can remain for many millions of years in sediments. Thus began an unexpected departure for my research, which then turned outward to studies of the cosmic dust flux, as measured in the rise and fall of helium-3 levels in sedimentary rocks. And this research in turn has led to confirming evidence that Earth was bombarded 35 million years ago, late in the Eocene epoch, by a shower of comets.

Gene Shoemaker immediately recognized the potential application of my helium-3 discovery and encouraged me to pursue the relationship between impacts and cosmic dust. He proposed a collaborative investigation of the uplifted sea-floor sediments now exposed in the Apennine mountains of northeastern Italy. These sediments carry an unusually complete record of impacts, including a late-Eocene layer highly enriched in iridium and shocked mineral grains.

In the spring of 1997, just a few months before Shoemaker's death, we worked together in the field along with his wife Carolyn and our Italian collaborator, Alessandro Montanari, to obtain samples of these late-Eocene rocks. The results of our investigation, published recently in *Science*, showed an increase in cosmic dust that coincided with the late-Eocene impacts (see Poag, "Backyard Bolides," page 6).

These findings represent a step toward answering a host of related questions about Earth impacts and the nature of impactors. Where do they come from? Are they mostly asteroids, or are they mostly comets? If they are comets, are they solitary, or do they come in rare but intense showers? Even with years of research, including telescopic observations and theoretical considerations of solar system bodies, as well as direct study of craters themselves, scientists have been unable to resolve these questions. Using helium-3 as a cosmic dust tracer may help us understand the observations scientists have gathered by these other methods.

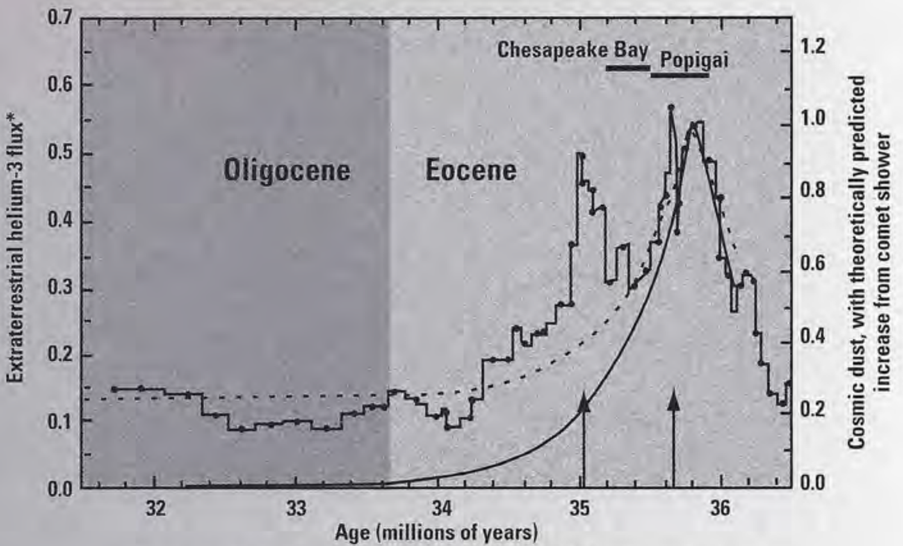
Anatomy of a Cosmic Dust Tracer

Let's begin with cosmic dust, the fine-grained extraterrestrial debris that rains down continu-

Measurements of helium-3 rise in sediments from the late Eocene, indicating an increase in the amount of cosmic dust falling to Earth (stepped curve). Arrows show the position of iridium anomalies, indicating impact by a comet or asteroid. The smooth curve is a theoretical prediction of helium-3 flux during a comet shower produced by a close stellar encounter, ignoring any contribution from asteroidal dust sources. The dashed curve is the same but offset to account for asteroidal dust, which is assumed to match the helium-3 baseline during the Oligocene.

Diagram by Kenneth A. Farley; redrawn by B. S. Smith

Measured Helium-3 vs. Modeled Cosmic Dust



*The standard unit of measure in this area of study is: 10^-12 cubic centimeters at standard temperature and pressure per square centimeter of Earth's surface per kiloyear.

ously on the Earth, presently at a rate of about 40 million kilograms (about 90 million pounds) per year. This dust originates from the grinding up of asteroids in the asteroid belt and from comets.

To detect extraterrestrial debris in ancient sediments, we need a tracer, or chemical species that is much more abundant in asteroids or comets than in Earth's surface materials. Because all bodies in the solar system originated from the same solar nebula, they were all born with similar chemical compositions. The key to distinguishing extraterrestrial fallout is that Earth has been very active geologically, experiencing extensive redistribution of its chemical constituents. Earth now has a core of iron metal, a mantle and crust of rocky material, and an atmosphere of nitrogen, oxygen, and other gases. This settling out of elements makes the Earth's surface chemically distinct from extraterrestrial matter, at least for some specific elements.

For example, the element iridium, a widely used tracer of extraterrestrial fallout, is in very low abundance on the Earth's surface because of its strong affinity for iron metal. That is, iridium is a siderophile (iron-lover), and early in Earth's history, when iron was sinking globally to form the core, iridium was efficiently extracted from the rocky portions of our planet. As a result, almost all the iridium Earth was born with now resides in its core. Therefore, iridium that we find in Earth's surface today had to get there by falling from space.

Helium-3 works as an indicator of cosmic dust for analogous reasons.

Over geologic time, volcanism has efficiently extracted gases from the Earth's interior to form the atmosphere. Unlike other gases, helium is so light that it is not gravitationally bound to Earth: it rapidly drifts out into space and is lost forever.

Helium has two isotopes: helium-3 and helium-4. Helium-4 is produced by natural radioactive decay, so its terrestrial abundance remains fairly high. But helium-3, like iridium, is extremely rare in the Earth.

How Helium Falls to Earth

In contrast, extraterrestrial material is extremely enriched in helium-3. While in space, extraterrestrial matter is bombarded by the solar wind (a stream of ions, rich in helium-3, emanating from the Sun). Cosmic dust particles have a large surface area exposed to solar-wind implantation, and the result is a helium-3 enrichment more than a million times greater than what we see in normal terrestrial material. Even a tiny fraction of extraterrestrial matter in terrestrial sedimentary rocks (a few parts per billion) can be detected using the mass spectrometer in my lab at the California Institute of Technology.

Bodies colliding with the Earth, be they tiny dust particles or kilometer-sized bolides, are traveling at high velocities relative to the Earth, typically tens of kilometers per second. When such objects strike the Earth, kinetic energy is converted into heat, which can melt or even vaporize them.

Any helium in objects subjected to intense heating is lost in the atmosphere and ultimately returns to space—it is not recorded in the sedimentary rocks on the Earth's surface. The only extraterrestrial debris delivered to the Earth's surface in significant quantities and at temperatures low enough to retain helium is fine-grained cosmic dust, which radiates heat efficiently during atmospheric entry. Thus helium-3 is a tracer only of tiny cosmic dust grains, typically smaller than about 30 micrometers in diameter (about 0.001 inch).

By studying the sedimentary record we have been able to determine how the accretion rate of cosmic dust has changed over geologic time. In the late Eocene we find a prolonged increase in the cosmic dust flux, beginning half a million years before and extending approximately 2 million years after the large impacts that produced the Chesapeake Bay and Popigai craters. These observations are in excellent agreement with 1980s theoretical work that describes what should occur during a burst of strongly elevated cometary activity—in other words, during a comet shower.

Somewhere about 100,000 AU from Earth (an Astronomical Unit is equal to 150 million kilometers, the mean distance between Earth and the Sun) lies the Oort cloud, a vast swarm of comets encircling our star. A passing star may have knocked a few of these comets out of safe orbits and sent them hurtling into the inner solar system. The late-Eocene craters may be evidence of such a comet shower. At left, we see Edwin Faughn's idea of how our solar system may look from inside the Oort cloud. Above is Don Davis' view of how our solar system may appear from a point well outside the Oort cloud.

Illustration at left: Edwin Faughn; illustration above: Don Davis, from The New Solar System, *4th ed., to be published December 1998*

A Comet-Shower Scenario

Our measurements in Italy revealed an approximately five-fold enhancement in the cosmic dust flux around the time of the late-Eocene impacts. The influx maximum coincided almost exactly with the impacts (see graph). However, the increase began about 0.5 million years before and declined slowly for about 2 million years after the impacts.

We can explain this particular pattern of influx and its association with several large impacts by supposing the advent of a comet shower. We hypothesize that the appearance of an enhanced cosmic dust flux about 36 million years ago indicates that the first of these comets had reached the inner solar system, bringing their dust along with them. For the next 0.5 million years or so the number of comets in the inner solar system rose, and at least two of the many comets collided with Earth to produce the Popigai and Chesapeake Bay craters. After these impacts, the cosmic dust flux decreased slowly to background levels, suggesting a slow dissipation of cometary activity. Note that the increase in cosmic dust falling to Earth came not from the impacts, which were high-temperature, helium-releasing events, but from the increased number of comets spraying cosmic dust around the inner solar system.

How would such a comet shower come about? Comet showers are a result of gravitational perturbations of the Oort cloud, a vast swarm of icy bodies in the outermost solar system. A star passing close to our solar system could propel a large number of new, long-period comets from the Oort cloud toward the Sun. Such gravitational perturbations must occur relatively frequently (on average about every 40 million years).

This comet-shower scenario readily explains the occurrence of multiple large craters in a short time span and also accords with recent observations of possibly cometary particles associated with a late-Eocene impact layer. We still need to do further work to establish the uniqueness of our hypothesis—that is, we need to establish that a comet shower is the only explanation that credibly fits the data from the late Eocene. We also need to establish whether comet showers are commonly associated with large terrestrial impact craters.

Because helium survives in sediments many hundreds of millions of years old, it is possible that we will be able to map the cosmic dust flux throughout a sizable fraction of Earth history. A team of researchers is presently embarking on this large undertaking. If successful, we will be much closer to understanding the role comets have played in the history of our solar system. My only regret is that Gene Shoemaker, who put this work on its present course and had a burning interest in the results, did not live to see the work to completion.

Kenneth A. Farley is Associate Professor of Geochemistry in the Division of Geological and Planetary Sciences of the California Institute of Technology.

Europa: Laye

What lies beneath the skin? That question consumes the thoughts of scientists exploring Europa. It has gone beyond the simple question of whether there is a water ocean beneath the ice; the evidence for that builds daily. Scientists are now collecting data to address more subtle issues, such as what has colored the Europan surface, and what is flavoring the probable ocean?

Europa imaging team leader Ron Greeley, offering a glimpse of the emerging mysteries, points to "a widespread, if not global, layer of dark material just below the surface." This layer is visible in the ejecta blasted from the ice crust by impactors. It's also seen along the strange triple bands crisscrossing the crust. It's seen in low-lying areas that may be dried puddles. It darkens the icy surface and delineates features. But what is it?

Members of the *Galileo* NIMS team (Near-Infrared Mapping Spectrometer) have just published a paper in *Science* that provides the beginnings of an answer. NIMS has detected the spectral signature of hydrated materials on Europa's surface. "Hydrated" means that water was injected into the minerals as they formed, and that process must have occurred in a fluid phase. So these hydrated minerals formed in liquid water. "That's why we're so excited about finding hydrated materials on Europa," commented Adriana Ocampo, member of the NIMS team and of the Planetary Society's Advisory Council.

So what sorts of hydrated minerals are they? The closest (though not exact) spectral match is to hydrated salts, similar to the magnesium sulfates common on the floor of Death Valley on Earth. In that exceedingly dry environment, water that pools on the surface reacts with minerals, forms salts, and evaporates. A similar freeze-drying process may occur on Europa, which despite its covering of ice has too little atmosphere to hold onto water vapor.

While most *Galileo* scientists accept the hydrated salts interpretation, there remains a

loose end. The salty areas are red and yell
imaging (SSI) cameras. They should appear w

One suggestion is that ultraviolet radia
up by Jupiter's tremendous magnetic field d
Consider also, as SSI team member Paul Geis
volcanoes "ends up painting the surfaces o
cleanest ice on Europa has a yellow tinge. I

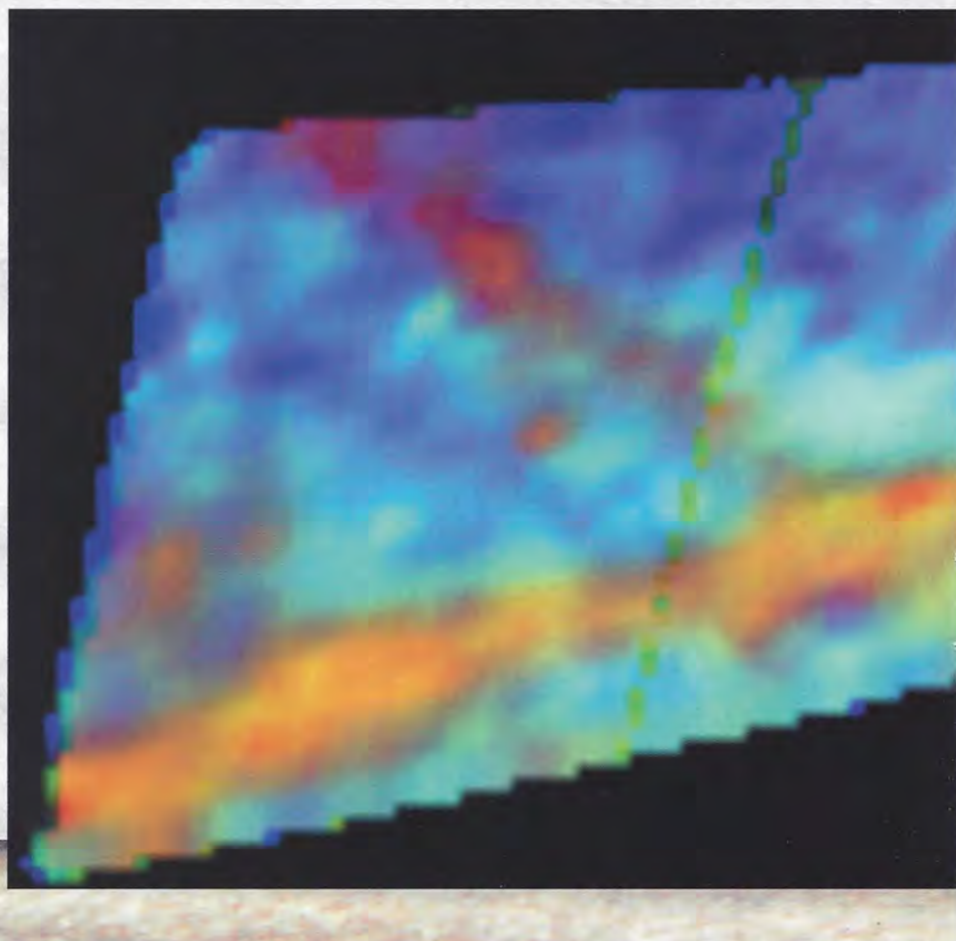
Geissler thinks the NIMS interpretation
full story. It doesn't explain what SSI sees a
component unaccounted for by salts or su

In a laboratory at Cornell University, Ca
manufactured hydrocarbon compounds th
the compounds tholins and speculated tha
a role in the chemistry leading to life. Acc
them with water ice, you get a good fit" wi

NIMS data, too, add to the suspicion th
(in chemistry, "organic" means carbon-con
cesses). The spectra indicate the possible pre
combinations on Europa.

Putting all this together, we get a pictur
which lies an ocean of water. The water in
that salty ocean there may be hydrocarbon

The possibilities we see in Europa are aw
admits, "certainly keep us awake at night."

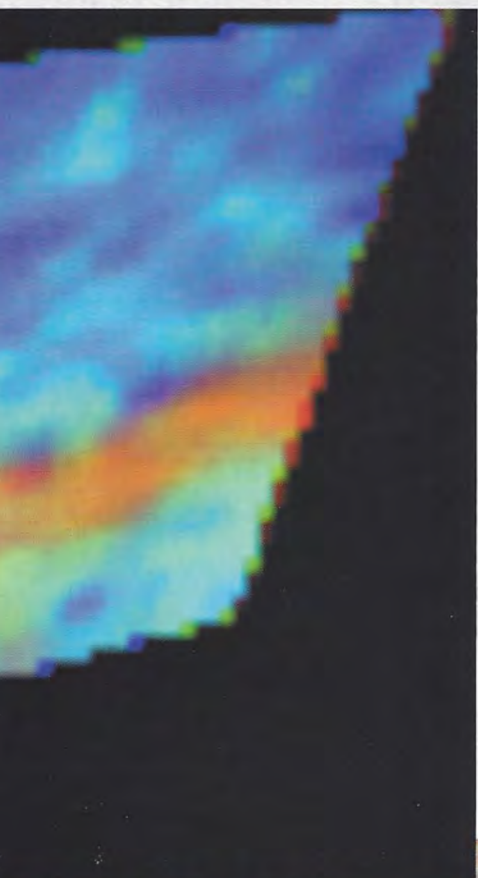


With high-resolution NIMS data, scientists have been able to determine that salty contaminants are prevalent in areas that look dark in visible light, including the dark features called linea. In this image, the red areas represent the highest concentrations of hydrated salts, with dark blue representing relatively pure water ice. Images: JPL/NASA

rs of Mystery

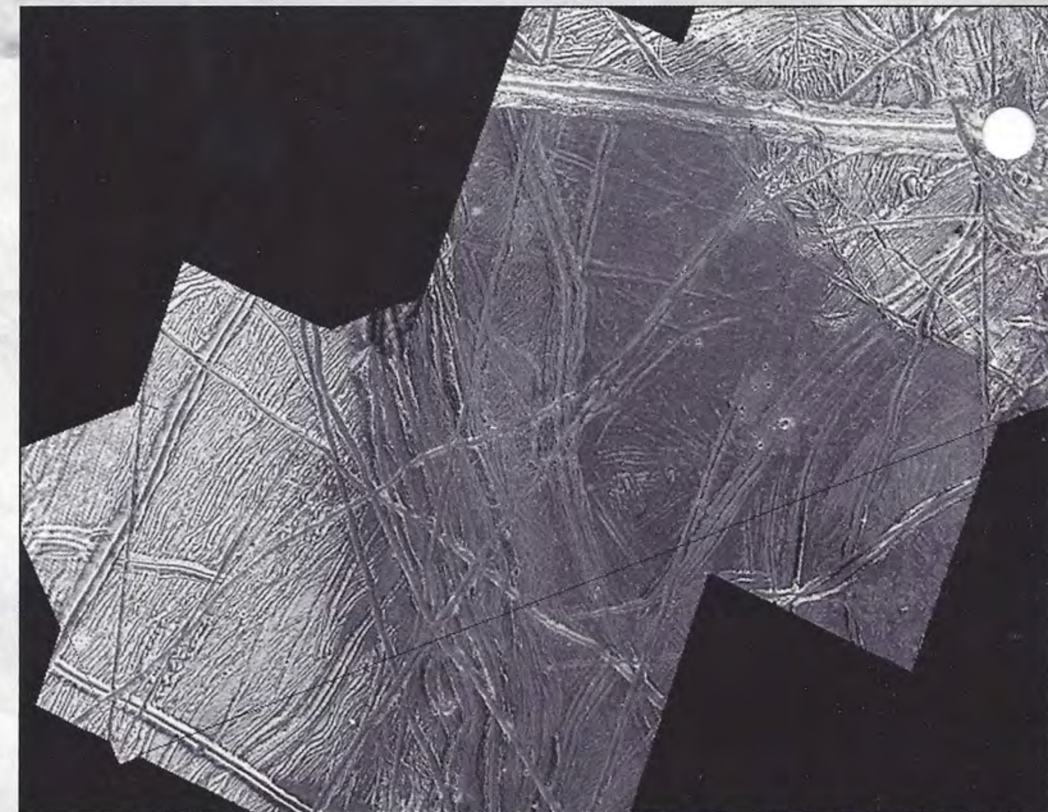
w in the visual spectrum of the solid-state
hite. Something is coloring them, but what?
ion from the Sun and charged particles whipped
rive chemical reactions that color the salts.
ler points out, that sulfur pumped out by Io's
Ganymede, Callisto, and Europa. Even the
suffers from second-hand sulfur."
a good one but adds, "I don't think it's the
t shorter [visible] wavelengths." SSI sees a red
fates. What could that be?
rl Sagan, Bishun Khare, and their colleagues
at took on a similar reddish color. They called
t these or similar compounds might have had
ording to Geissler, "If you take tholins and mix
h what the *Galileo* cameras are seeing.
t Europa may contain organic compounds
aining and does not necessarily imply life pro-
sence of carbon-hydrogen and carbon-nitrogen

e of a moon covered in a crust of ice, beneath
that ocean is flavored with salts. And within
, building blocks of life.
some. And those possibilities, Geissler readily
—*Charlene M. Anderson, Associate Director*



Galileo's NIMS sees in different wavelengths from the solid-state imaging system (SSI), which approximates the sensitivities of the human eye. NIMS is designed to identify compounds that cover planetary surfaces. It's a powerful instrument, but it does not see things the way we do, and so images created from NIMS data look a bit alien.

This is how Europa looks in one of the NIMS passbands. The purple regions are made of relatively pure ice, while the yellow-green areas are contaminated with darker materials. The NIMS science team interprets the dark areas as evaporite deposits—formed when water from below, rich in dissolved salts, erupted through the ice, vaporized, and left behind its salty residue. This interpretation accords with the hypothesis that an ocean lies beneath the Europan crust.



Right: To the west (left) of this mosaic's smooth, dark central region, we see a cliff and terraces, perhaps formed by faulting similar to that occurring on Earth. To the east lie gentle slopes. At the center some sort of dark material has erupted from beneath, covering bright terrain and ridges. Scientists believe that the dark material came out as a fluid or slush, flooding nearby impact craters, which may be secondaries formed by debris from the impact that created Mannann'an (see page 18, top). Scientists built this mosaic from images taken on March 29, 1998.

Right: Each world we've visited via our robot explorers has its own way of being beautiful. This view of ridged plains on Europa is, to this writer's eye, one of the most beautiful images yet returned from another world. It looks a little different from other *Galileo* images because it was taken with the Sun higher in Europa's sky. This lighting enhances the frost covering the surface and gives the monochrome image an almost silvery sheen.

Tectonic forces, probably driven by tidal heat within Europa's rocky core, repeatedly push and pull on the icy crust, cracking it and forming sets of long, parallel ridges that crisscross each other. Dark ice, probably contaminated by salts from an ocean beneath, pushes up through the ridge floors, leaving dark deposits along the margins and in the valleys. In the upper right corner, we see evidence of this process in a distinct dark ridge about 2 kilometers wide (1.2 miles), which has in turn been deeply cut by fractures that continue onto the plains.

Galileo's solid state imaging system took this image on December 16, 1997. It covers an area about 20 kilometers on each side (12 miles), showing details as small as 26 meters.

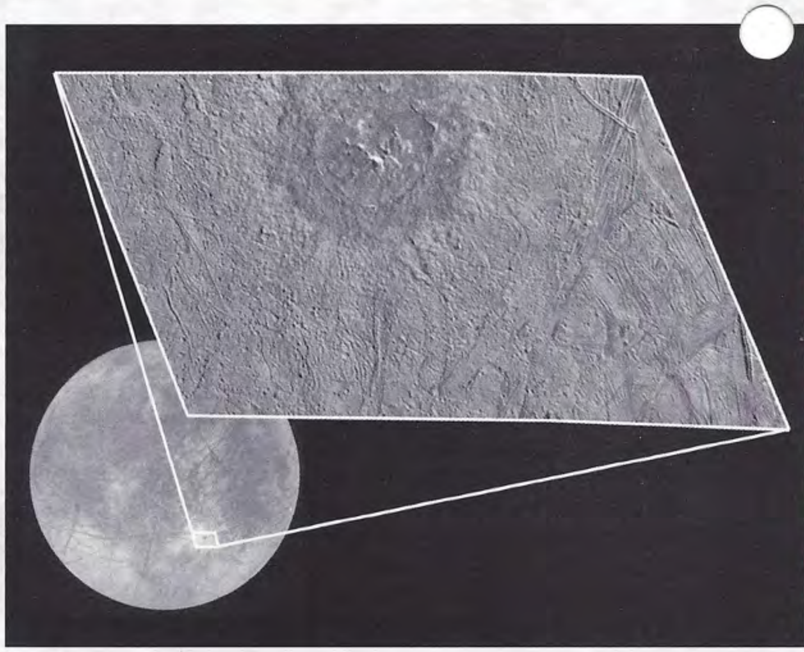
Right: On its closest pass by Europa, *Galileo*'s cameras took this oblique image of the moon, giving us a view similar to what you would see from an aircraft window. Features at the bottom of the image appear much closer than those at the top. Bright ridges alternate with low valleys filled with dark material. Near the center of the picture, the ridges and valleys give way to dark, jumbled hills. The small, circular features are probably impact craters.

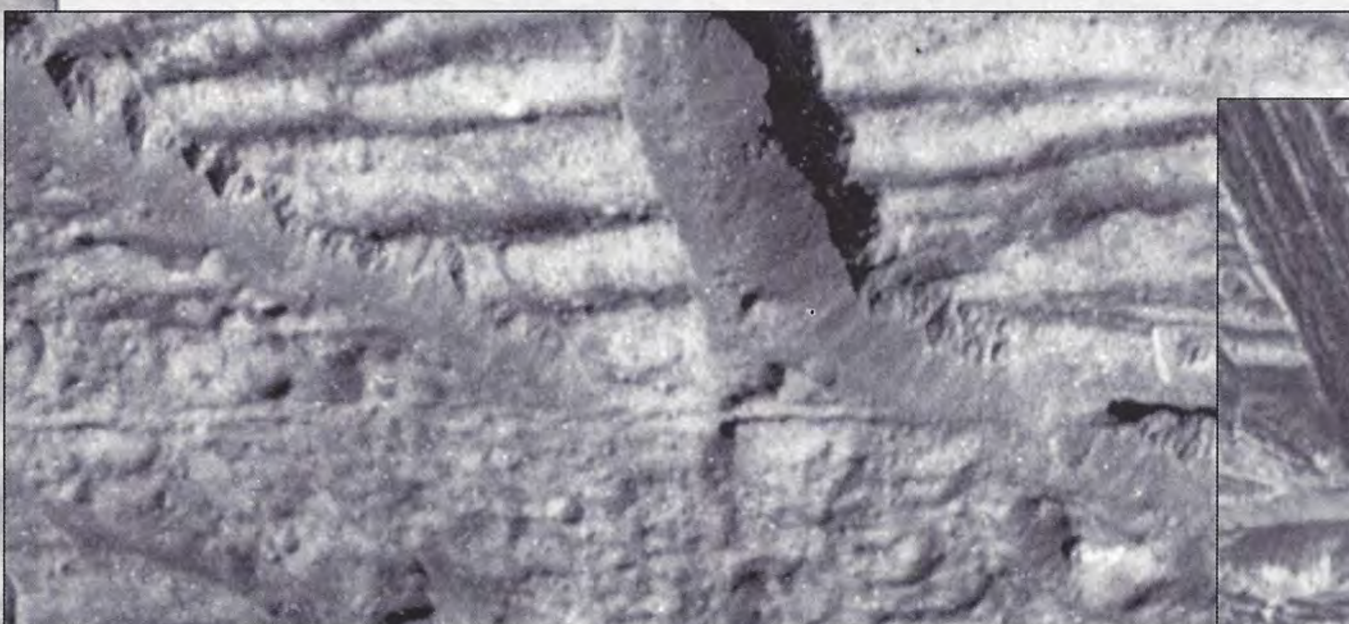
This is the highest-resolution image that *Galileo* will return from Europa; it was taken on December 16, 1997 from only 560 kilometers above the surface (335 miles). The area covered is about 1.8 kilometers wide (1 mile), and details as small as 6 meters are visible. IMAGES: JPL/NASA

Impact craters on Europa are different from anything found on other solar system objects. At right and far right, we see views of Pwyll, the most distinct large crater on this moon. In the global view, rays radiate from the crater, indicating that it is geologically young. Pwyll, about 26 kilometers across (16 miles), is surrounded by a halo of dark material thrown out by the impact. Beyond the halo are small, bright secondary craters, formed by impact debris.

The enlarged view coming from the small parallelogram combines data from two flybys. It shows that Pwyll's floor is at nearly the same level as the surrounding plain. This profile, different from craters observed on other bodies, suggests that shortly after the meteorite struck, the warm, soft Europan crust couldn't hold the shape of classic impact craters, typically formed in cold, stiff material.

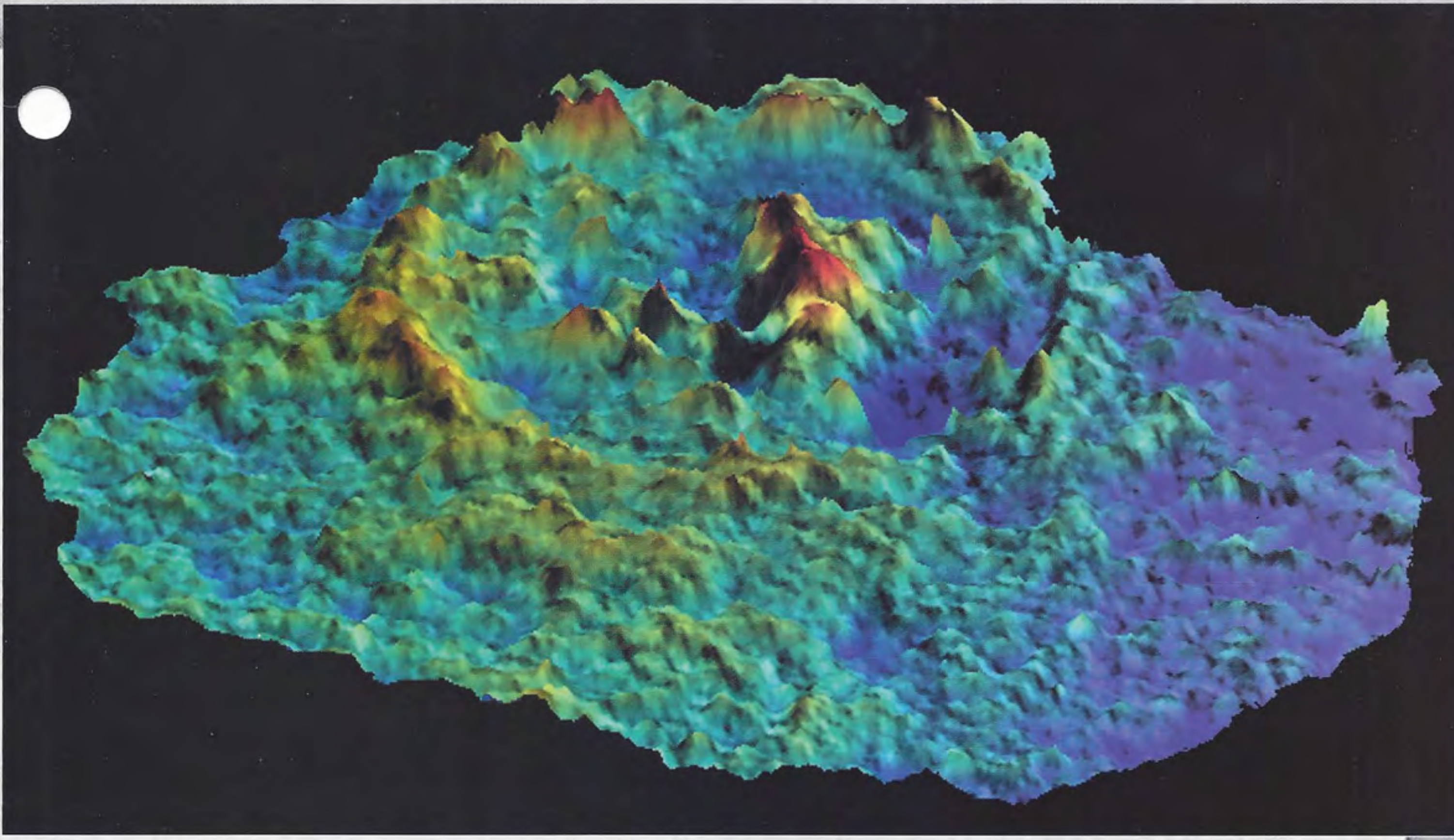
Scientists at the German Aerospace Research Establishment (DLR) created the color perspective view (with a vertical exaggeration four times the true proportions) from the same data as the close-up. Here we see again how strange this crater is. The central peaks rise more than 600 meters, higher than the crater rim. IMAGES: JPL/NASA

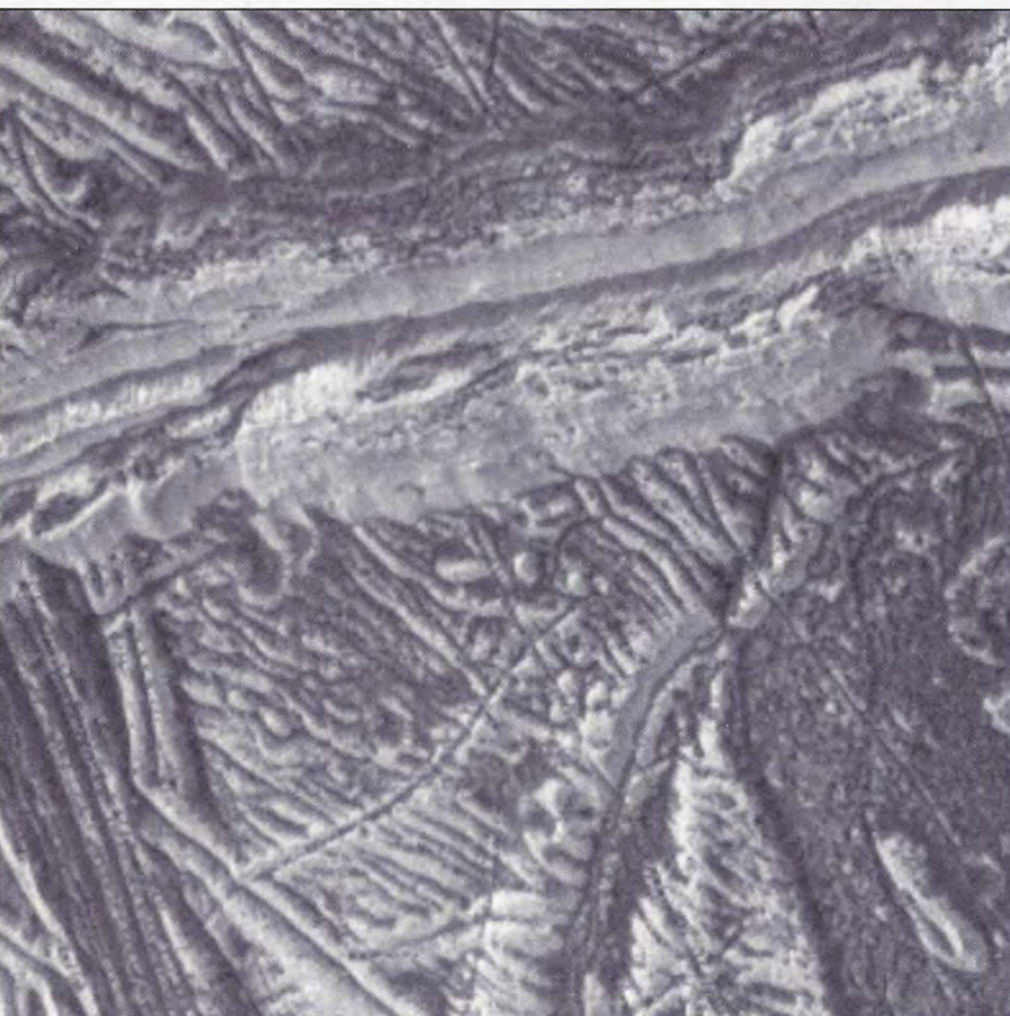




Above: Where icy plates crack, drift apart, twist around, and freeze back into a solid crust, you see a terrain that looks a bit chaotic. Hence the name Conamara Chaos for this part of Europa. In the top half of this image is a series of ice plateaus that look somewhat like corrugated cardboard—except that they end in cliffs more than 100 meters high. At the base of the cliffs you can pick out house-sized blocks of debris. A fracture about as wide as an earthly freeway runs across the image.

This high-resolution image, taken on December 16, 1997, shows details as small as 9 meters across. It covers a region 1.7 by 4 kilometers (1 by 2.5 miles).

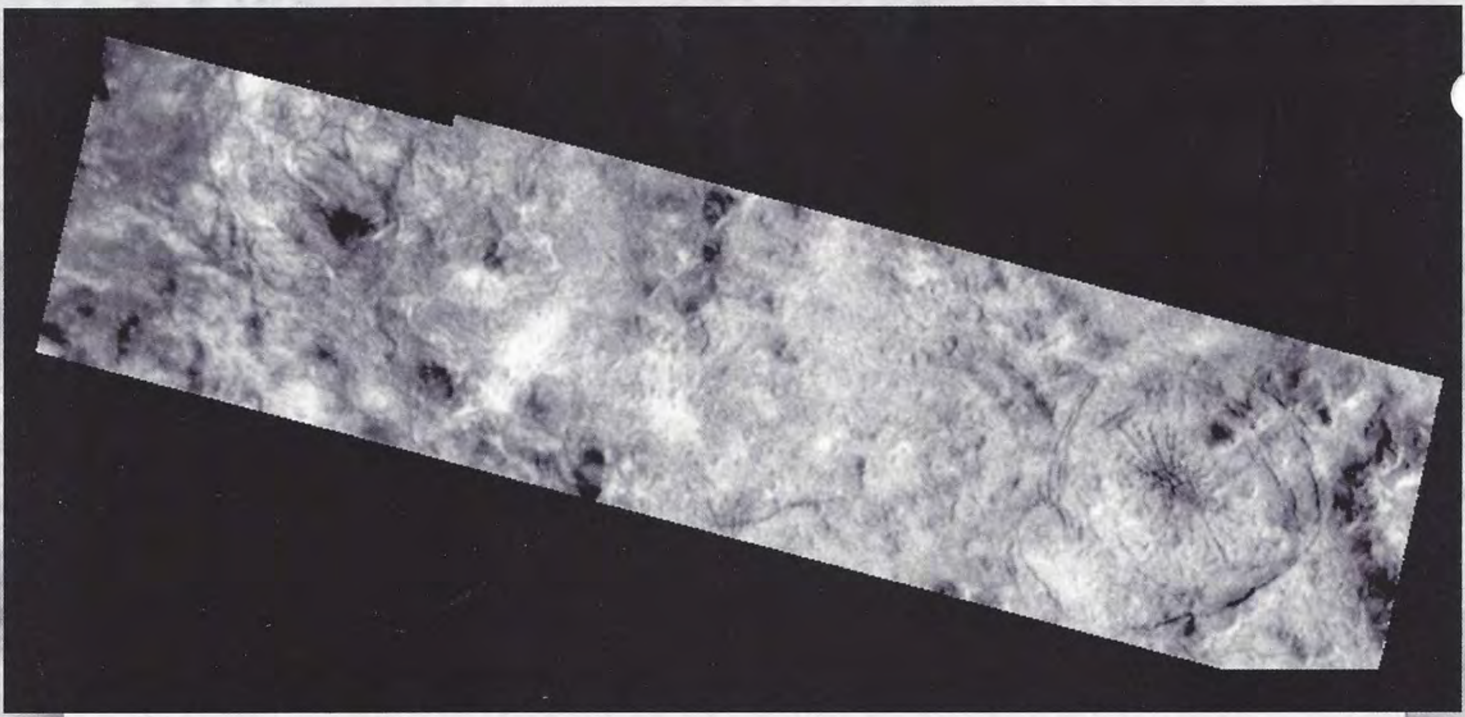




LEFT: NATURAL CATASTROPHE SEEMS WRITTEN ACROSS THIS PIECE OF EUROPA, BUT THE FORCES AT WORK ARE UNLIKE ANY THAT RIP APART EARTH'S ROCKY SURFACE. HERE A GLOBAL CRUST OF ICE FLOATS OVER A LIQUID OR VISCOUS LAYER—AN ALIEN GEOLOGY THAT SCIENTISTS ARE TRYING TO UNDERSTAND. TWO DISTINCT RIDGES DOMINATE THIS REGION. THE OLDER, RUNNING FROM TOP LEFT TO BOTTOM, IS DARK, RELATIVELY FLAT, AND MARKED WITH WITH SMALLER LINEAR RIDGES AND TROUGHS. A YOUNGER, ROUGHER, AND BRIGHTER RIDGE, WITH TWO RAISED RIMS AND A CENTRAL VALLEY, CUTS ACROSS THE OLDER FEATURE. THE OLDER RIDGE IS ABOUT 2 KILOMETERS ACROSS (1.2 MILES), THE YOUNGER ONE ABOUT 5 KILOMETERS (3.1 MILES).

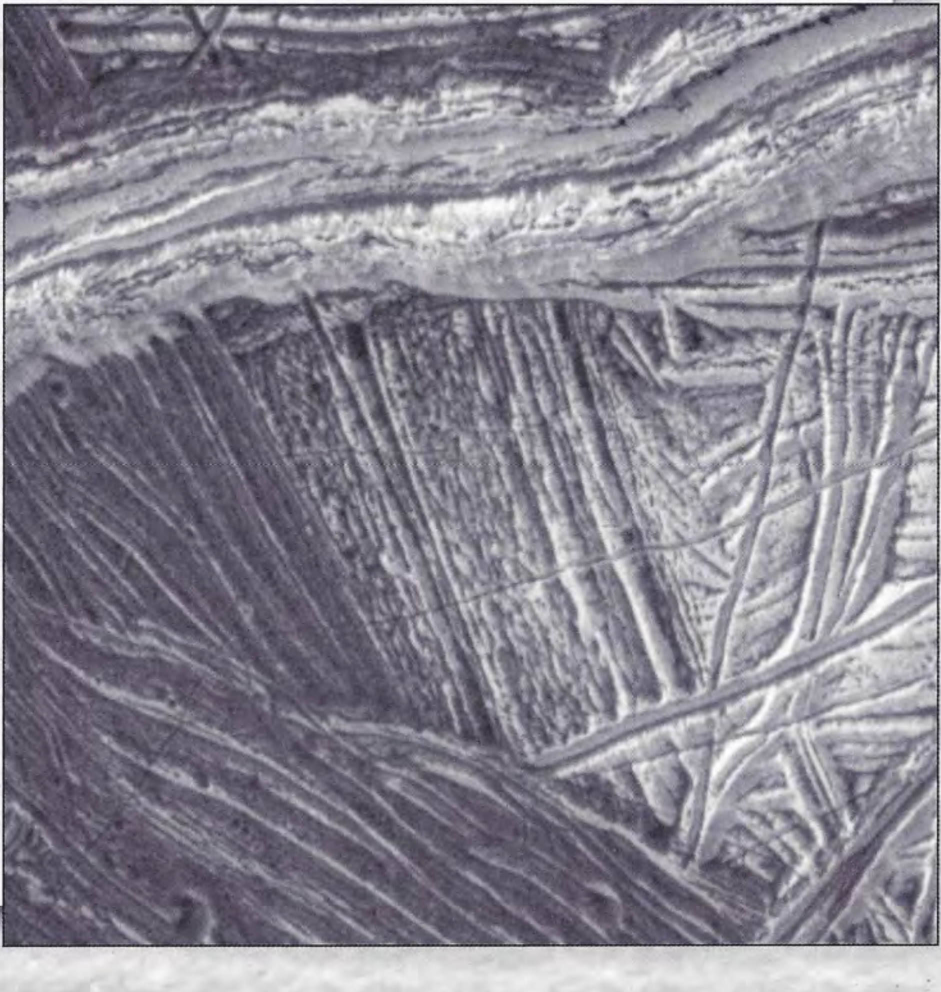
AT THE BOTTOM RIGHT OF THE IMAGE IS A DARK, SMOOTH REGION, ABOUT 30 SQUARE KILOMETERS IN AREA (12 SQUARE MILES), WHERE WARM ICE HAS WELLED UP FROM BELOW AND LAPPED A BRIGHT, HIGH AREA, FORMING AN ISLAND.

THIS IMAGE, TAKEN ON DECEMBER 16, 1997, COVERS SOME 15 BY 20 KILOMETERS (9 BY 12 MILES). THE SMALLEST FEATURES VISIBLE ARE ABOUT 26 METERS ACROSS.



Above: Large impact craters are rare on Europa. The mobile, icy crust heals such scars in a geologically short time (perhaps millions of years). This paucity of craters indicates that the surface we see is young and active—which supports the idea that an ocean lies below.

In this image we see a slice across the crater Mannann'an, showing the rim (left) and interior. At the right edge of the image is a large pit, with concentric cracks surrounding it and dark fractures radiating from its center. The reddish brown areas are ice, perhaps contaminated by hydrated salts or other substances. The bluish areas are purer ice. This image, taken on March 29, 1998, covers an area about 18 by 4 kilometers (11 by 2.5 miles), with resolution of details as small as 40 meters across.



Right: In the recent past, Europa's crust cracked, the pieces pulled apart, and dark-stained ice welled up and filled the voids and froze. That's the story scientists tell of this tortured region of Europa. In the lower left there is dark terrain with textured lines bending slightly along its surface. To the right lies an older region, brighter and crisscrossed with ridges. Cutting across both features is a younger, bright ridge, containing numerous small terraces and troughs filled with dark, contaminated ice. Again and again, Europa's crust has been rent by energy emanating from below—perhaps through volcanoes driven by tidal forces raised by the giant planet Jupiter and the larger Jovian moons, Ganymede and Callisto.

This image covers an area about 10 kilometers square (6 miles to a side), with details as small as 26 meters visible. Images: JPL/NASA

World Watch

by Louis D. Friedman

Washington, DC—Congratulations, members of the Planetary Society. We achieved a great victory in our efforts to restore funding within the US Mars exploration program that will allow experiments related to human exploration of Mars to be accommodated on the 2001 Mars Surveyor lander.

In May, we wrote to you about the deletion of these funds from the NASA budget and asked you to join a campaign urging the House and Senate Appropriations committees to restore the funds. Many thousands of our members responded with postcards directed to key committee chairpersons and to "Leaders of the World's Spacefaring Nations."

Congress responded with favorable action in both the House and Senate Appropriations committees. An additional $20 million was made available to the 2001 Mars Surveyor project. Our postcards and support (including many letters, press releases, testimony to Congress, and background meetings) were effective—showing the significance of public interest in Mars exploration. This success also shows the value of citizen participation in the space program. Representative Jerry Lewis, chair of the House Appropriations subcommittee that deals with the NASA budget, commented: "The Planetary Society deserves a lot of credit for bringing the issue to the attention of members of Congress. Its members helped communicate the importance of providing additional funding for the Mars 2001 mission."

The Mars program now can carry on with its plan for launches in 2001 and 2003 that lead up to the Mars Sample Return in 2005. The 2005 sample return is intended to be the first of several.

With the increased money, the 2001 mission will now include a *Sojourner*-like rover with new instruments and a robotic arm to bring samples to a wet chemistry laboratory on board the lander.

Originally, the 2001 Mars Surveyor lander was to have had a large rover (greater than 45 kilograms, or 100 pounds) in addition to the lander and orbiter. However, the rover plans proved to be too ambitious and had to be delayed until 2003. Some of the rover payload—the camera and a thermal emission spectrometer—will be included on the 2001 Mars Surveyor lander along with the experiments related to human exploration of Mars. The most notable of these experiments is the first test of part of the system for making propellant from resources indigenous to Mars (see the March/April 1994 *Planetary Report*, page 15).

Washington, DC/Paris—Another gain for the Mars program was achieved in June with the signing of an American-French agreement to conduct the 2005 Mars Sample Return mission jointly. France is offering an Ariane 5 to launch the mission and in return will be integrated into Mars Surveyor science and mission planning. The French may also build the orbiter for the mission.

Under the agreement, the US may have opportunities to add very small payloads (in the range of 100 kilograms, or 220 pounds) as piggyback or secondary payloads to other launches of the Ariane 5. Study of this possibility will focus on missions as early as 2001.

Additional international cooperation in Mars exploration comes from joint planning by the European Space Agency and the Italian Space Agency for use of the *Mars Express* orbiter as a communications satellite for the 2003 Mars Surveyor and the 2005 Mars Sample Return. Russia has been prevented by financial difficulties from carrying out Mars missions in cooperation with these programs, but Russian science instruments are included on NASA's 1998 Mars orbiter and lander and on the 2001 Mars Surveyor orbiter.

Louis D. Friedman is Executive Director of the Planetary Society.

The Planetary Society Presence on Planetary Missions

- *Magellan* The mission name came from entries in a Planetary Society contest.
- *Mars Pathfinder* The rover *Sojourner* was named in a Planetary Society contest; our members' names are inscribed on the MAPEX documentation chip aboard the lander; the lander is now named the Carl Sagan Memorial Station in honor of the Society's co-founder.
- *Cassini* We helped collect and process 600,000 signatures that were recorded on a CD and placed aboard the Saturn-bound spacecraft.
- *Mars Polar Lander* The Mars Microphone, the first experiment aboard a planetary mission to be funded by a membership organization, was developed through Society cooperation with the University of California Space Sciences Laboratory and the Russian Space Research Institute.
- *Stardust* We helped collect names, including all our members' names, for transport to a comet and back.
- **Mars Surveyor 2001** Watch for an announcement soon!

Questions and Answers

Given the planet's very low atmospheric pressure, how could enough water have existed on Mars to create a flood? Water would boil and then evaporate rapidly at Mars' 7 millibar atmospheric pressure.
—William Carrington, Tokyo, Japan

There are two major types of Martian channels; both were most likely formed by water. The Martian features that most resemble terrestrial river valleys are the runoff channels. These features must have formed when conditions on Mars (such as a warmer atmosphere and greater atmospheric pressure) made its surface capable of supporting liquid water.

This Mars Global Surveyor *image, taken on January 9, 1998, shows the transition between a cratered and channeled upland and a lower-lying chaotic terrain. The term "chaotic terrain" describes areas where Mars' surface has seemingly collapsed into a jumbled mass at a lower elevation than the surrounding region. Many of the large flood channels emerge from this type of terrain. However, if the low-lying area in this image had been formed simply by collapse, the cliff would probably not have such a distinct, raised rim. The strip at right shows a portion of the boxed area in the full image.*

Image: MSSS/NASA

However, the Martian *outflow* channels are much larger and would not have needed favorable surface conditions to form. Features in the outflow channels are similar to features found in catastrophic flood channels on Earth. The amount of water necessary to produce the Martian catastrophic floods is estimated as about 10 million to 100 million cubic meters per second, a flow about 100 times greater than the flow from Earth's greatest river, the Amazon. All this water most likely came from beneath the surface.

Although the current temperature and pressure at the Martian surface are too low to allow the presence of liquid water, there are places beneath the surface with pressure high enough and temperature warm enough for water to exist as a liquid.

Here is a scenario to consider. Tectonic activity can force a planet's surface to tilt. Such an event could cause a once-flat reservoir of water under the surface to tilt also. Gravity would then pull the now-higher areas of water against the lower areas. With enough water, the force could be large enough to break through the surface and release the water, which might travel for hundreds of kilometers before it all boiled away into the Martian atmosphere.

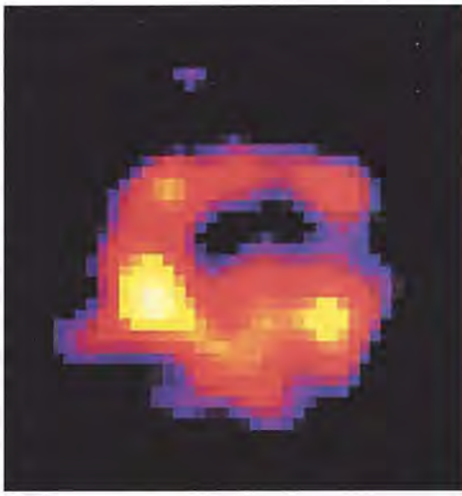
—JULIE RATHBUN, *Cornell University*

What effects would a planet the size of Jupiter produce on Earth if it came close to our home planet? Could it, for example, produce a variation in the angle of Earth's rotational axis or produce instabilities in the atmosphere and ocean tides?
—Antonio Lopez, Mexico City, Mexico

If Jupiter were in a circular orbit much closer to that of Earth than it is, then our planet's orbit would be destabilized. A rough estimate is that large instabilities would ensue if Jupiter's orbit were as near as the present orbit of Mars, perhaps leading to the collision of Earth and Jupiter or to the ejection of Earth from the solar system. Fortunately, Jupiter remains at a safe distance, and Earth's orbit is stable enough to last for billions of years.

If Jupiter somehow left its present orbit and passed close to Earth (which would require some extremely unlikely extra-solar event, such as a near-collision of the Sun with another star), then dramatic changes to Earth and its orbit would likely occur. Huge tides would be raised in the ocean and in the solid parts of Earth. If the giant planet were to pass as close as the orbit of the Moon (say 350,000 kilometers, or about 220,000 miles), then tides 10 kilometers (about 6 miles) high would rupture Earth's crust. Earthquakes, tsunamis, and ocean tides several kilometers high would destroy most structures on land. The orientation of Earth's axis would probably not change significantly, due to the short duration of the encounter. It would probably tip just a few tenths of a degree with a lunar-distance passage.

Another interesting effect might be the immersion of Earth in Jupiter's immense magnetosphere, potentially disrupting Earth's magnetosphere and resulting in atypical auroral activity and magnetic storms. A close passage of Jupiter might well remove the Moon from orbit, with long-term consequences for the stability of Earth's tilt and climate. (The gravitational influence of the Moon acts to



This false-color image shows the emission from dust particles surrounding the star Epsilon Eridani. The brightest (densest) regions are yellow and red. Blue and black represent areas with little dust.

Image: Joint Astronomy Centre

stabilize the Earth's axial tilt of 23.5 degrees, preventing the large oscillations that are thought to afflict Mars' climate on 100,000-year timescales.)

If any human observers remained alive, the appearance of Jupiter in place of the Moon in our sky would be impressive. Jupiter would look about 50 times as big and reflect about 6,500 times as much sunlight as does the full Moon.

—PHIL NICHOLSON, *Cornell University*

Why is it that* Pioneer 10 *has stopped transmitting, yet* Pioneer 11 *and* Voyagers 1 *and* 2 *still are?
—Matt Budde, Colorado Springs, Colorado

Pioneer 10 was launched March 2, 1972, about five and a half years before *Voyagers 1* and *2*. Until the faster-moving *Voyager 1* recently surpassed it in distance from Earth, *Pioneer 10* held the record for being the most distant human-made object. While it continues to transmit its weak radio signals over a distance of nearly 10 light-hours (about 10.8 billion kilometers or 6.7 billion miles), the electrical power on the spacecraft has become insufficient to collect useful data from its scientific instruments, and so it was retired by NASA on March 31, 1997, more than 25 years after launch.

Pioneer 10's twin, *Pioneer 11*, was launched March 6, 1973. It was the first spacecraft to fly by Saturn. *Pioneer 11*'s power source continued strong enough to permit spacecraft operations for more than 22 years but then gave out. The last communications were received from *Pioneer 11* in November 1995.

Voyagers 1 and *2*, with larger, longer-lasting power sources and more capable scientific instruments, are expected to continue transmitting useful scientific data until the year 2015 or beyond. Their current mission is to find and characterize the outer edge of the Sun's magnetic field, called the heliopause. There, for the first time, we will be able to sample the nature and chemical composition of true interstellar space.

—ELLIS D. MINER, *Jet Propulsion Laboratory*

Factinos

Scientists have discovered what appears to be a developing planetary system around the nearby star Epsilon Eridani (see image at left).

"What we see looks just like the comet belt on the outskirts of our solar system, only younger," said Jane Greaves, who led the international team of astronomers from the Joint Astronomy Centre in Hawaii, the University of California at Los Angeles (UCLA), and the Royal Observatory in Edinburgh. "It's the first time we've seen anything like this around a star similar to our Sun. In addition, we were amazed to see a bright spot in the ring, which may be dust trapped in orbit around a planet."

"If an astronomer could have seen what our solar system looked like 4 billion years ago, it would have been very much as Epsilon Eridani looks today," said team member Benjamin Zuckerman of UCLA. "This is a star system very like our own, and [it is] the first time anyone has found something that truly resembles our solar system. It's one thing to suspect that it exists, but another to actually see it, and this is the first observational evidence."

The ring of dust particles around Epsilon Eridani was revealed in a short-radio-wavelength image (below visible light in the electromagnetic spectrum) using the 15-meter James Clerk Maxwell Telescope at the Mauna Kea Observatory in Hawaii.

—from the Joint Astronomy Centre

❖

On June 22 scientists reported that one of our Sun's closest neighbors, a star only 15 light-years from Earth, has a planet at least 1.6 times as massive as Jupiter. The unseen planet was detected by the characteristic wobble of its parent star, Gliese 876. Of all the stars believed to have planets, Gliese 876 is the closest to Earth and the smallest, possessing only one-third the mass of the Sun.

Finding a planet around one of the first low-mass stars to be studied hints that planetary systems "may be a common occurrence among stars that are quite different from the Sun," says Geoffrey W. Marcy of San Francisco State University and the University of California at Berkeley.

Two hours after Marcy announced these findings at a symposium of the International Astronomical Union in Victoria, British Columbia, he received an e-mail reporting that other researchers had independently found evidence of the same planet. Xavier Delfosse of Geneva Observatory in Switzerland and Grenoble University in France and his team analyzed light from Gliese 876 using spectrometers at the Haute-Provence Observatory in France and the European Southern Observatory in La Serena, Chile.

—from Ron Cowen in *Science News*

❖

Jupiter's moon Callisto appears to have a magnetic field of its own and an ocean. At the annual spring meeting of the American Geophysical Union, scientists analyzing *Galileo* data reported strong evidence of a magnetic field induced in an ocean beneath Callisto's surface by Jupiter's powerful magnetic field.

Jupiter's magnetic field is tilted and wobbles as the planet rotates. In a salty ocean, a good conductor, this moving field would induce electrical currents and create a magnetic field, which on a Jovian moon would be oriented roughly opposite to Jupiter's, as observed by *Galileo* at Callisto. Callisto's ocean may have been created by internal heat (from radioactive decay) melting some of the moon's ice.

"This is an astonishing result," says planetary physicist David Stevenson of the California Institute of Technology in Pasadena, because from the outside "Callisto looks dead."

—from Richard A. Kerr in *Science*

News and Reviews

by Clark R. Chapman

In the July/August issue, I wrote about scientific hype in the news, exemplified by serious treatment of the Face on Mars and by headlines about mini-comets, asteroid impacts, and Europan sub-ice life. I suggested that scientists and their institutions bear responsibility to help the media "get it right."

Other recent examples abound. The *Lunar Prospector* site on the World Wide Web screams, "Eureka! Ice Found at Lunar Poles." There has been no peer-reviewed publication of this conclusion since the March press conference. The Web site's fine print says that only a fraction of a percent of the polar soils is ice, and the buzz at scientific meetings is skeptical that even that much is correct. The point is that this is not a *published* result, but it has entered public consciousness as fact.

In May, there was hullabaloo about Hubble Space Telescope (HST) snapping the first image of a "possible" planet near another star. Announced prematurely, before any observational checks were done to rule out alternative interpretations, the inference was perhaps appropriately scheduled as the topic of an obscure talk among hundreds at the June American Astronomical Society meeting. The media might have noticed and given it play, but the NASA press release guaranteed front-page headlines.

It seems that half of the space-science stories that receive public attention are premature, flaky, overhyped, or simply wrong. Fast and loose reporting is just the most public aspect of a trend within scientific publication that deeply disturbs me. I don't have a simple solution, but let me describe the problem.

There is a tradition in science, taught to students writing PhD theses, that a research paper should provide all of the details about the assumptions, the methodology, the data reduction, and conclusions—placed in the context of a thorough discussion of the previous literature on the topic—so that another researcher could replicate the experiment or at least fully understand it. This full accounting of research helps ensure that the next steps taken are on a sound footing.

Before publication, such articles are supposed to be extensively peer-reviewed, first by a researcher's colleagues and then by often-anonymous, outside referees, so that problems can be identified and addressed or corrected prior to a paper's appearing in what is called the "archival literature." Only then has it come as close as it can to being a scientific result.

Publishers' Pressure

This tradition was once a reality. It is a joy to read papers of the great physicists and astronomers from the first decades of this century. Often written with a literary command of language, their papers are complete, sometimes even describing blind alleys that had been pursued before the correct path was found. Such papers are published no more. Modern journal editors, responding to budgetary pressures, impose page limits on papers and inevitably require papers to be shortened if they do much more than introduce the topic and describe the results.

The American Geophysical Union has even instituted (over my dissent when I edited *Journal of Geophysical Research—Planets*) an "excess page charge": any article over 12 pages long, no matter how concisely written or densely filled with important information, is deemed "too long" and is penalized. Details that were once relegated, in small print, to appendices and footnotes are now often omitted altogether. Moreover, bits and pieces of research projects are now rushed into print in order to build up paper counts, which often influence funding, hiring, and promotion decisions.

Weekly, rapid-publication journals (*Science* and *Nature*) have editorial policies—for example, fixed word-count limits—that prohibit complete research articles, and their policies affect publication in other journals through the requirement that the same work not be first published (in adequate detail) elsewhere.

It's sensible to publish important research in multiple journals aimed at different audiences (for example, specialists, the broader space-science community, and the general scientific community); though often done, multiple publication is considered to border on the unethical. Increasingly, scientists, just as much as the general public, are forced to accept on faith the uncheckable conclusions of other scientists. The archival papers become ever shorter, shoddier . . . and unread.

Instant Results

No wonder some scientists now pride themselves on never reading the journals but rely instead on Internet preprints as the source of their up-to-date knowledge about what's happening. In the cases of lunar water ice or the HST extra-solar planet, even *that* isn't possible. (Two months after the hype, I clicked on a link for a preprint of the HST planet analysis, but all I got was an 11-line abstract.)

Scientists turn more and more to what has been called the "invisible college": conversations in the halls at meetings, e-mail discourse, and even science news articles in newspapers and magazines (including this one). I am all in favor of Public Outreach—the transfer of NASA's scientific discoveries to the public (who pays for the research) and the integration of the results into our culture. But I worry that science increasingly mimics its own Public Outreach. Science is balkanized into ever narrower bits of research, reported in sound bites long before the process of peer-review has even begun. What can we do to preserve the core elements of scientific peer-review and publication in the Age of the Internet?

Clark R. Chapman testified before the House Subcommittee on Space and Aeronautics on May 21 about the asteroid/comet impact hazard.

Society News

Red Rover, Red Rover Hops on an Asteroid

The Planetary Society's exciting Red Rover, Red Rover student project will soon reach a near-Earth asteroid. In a partnership with the Jet Propulsion Laboratory team that is building the nano-rover for Japan's *Muses C* mission, scheduled to land on an asteroid in 2003 and return samples to Earth in 2006, the Planetary Society will develop educational materials and activities related to the mission and remote nano-rover exploration.

The challenge for us will be devising activities that offer students the simulated sense of remotely maneuvering a rover within an asteroid's microgravity environment. The actual *Muses C* nano-rover will be capable of hopping and jumping within an asteroid's low gravity field but will need to be programmed so that its leaps do not put it into orbit around the asteroid.

Muses C is scheduled to launch in 2002. *—Louis D. Friedman, Executive Director*

Society Database Debugs for 2000

Like many organizations preparing for the turn of the millennium, the Planetary Society has been dealing with the year 2000. A new membership accounting records system is currently being installed at Society headquarters, replacing a database originally written in the 1970s. The old system has the "2000 problem," as members who have extended their renewals for several years may have already discovered.

Our new system will be an improved, modern database that will keep track of the hundreds of thousands of members who circulate through the Society's files, along with their millions of annual transactions.

For members who would like to try out the new system and see if it really can deal with the year 2000, send your advance renewals for the 21st century!
—Cindy Jalife, Director of Membership and Programs

Survey to Help Guide Society in Next Decade

We are now preparing a survey to gather information from random samplings of our membership to help us determine the directions the Planetary Society will take during the next decade.

For the first time in more than 10 years, we will be asking your assistance in providing us information about why you feel membership in the Society is important, what you believe are the organization's strongest assets, what we need to change, and how we can serve our members and our mission during this changing time in space exploration.

Our current plan is to mail surveys out during the beginning of 1999. Please check your mail for your survey questionnaire and return it as soon as possible. We need your input.
—Bill McGovern, Production Editor

Sun Microsystems to Power Web Efforts

Thanks to Sun Microsystems, the Planetary Society is now expanding its World Wide Web sites on a powerful Ultra 2 computer. Sun's donation of software and hardware worth more than $33,000 has enabled the Society to make our home page faster, more colorful, and more complete—ultimately providing more information about exploring the cosmos.

Keep checking our three Web sites for notices about new Internet information and services:

- The Planetary Society home page at http://planetary.org
- The Planetary Society's SEARCH: The Site for the Search for Extraterrestrial Life and Intelligence at http://seti.planetary.org
- The NEO Page at http://neo.planetary.org

—Michael Haggerty, Manager of Electronic Publications

More News

Mars Underground News:
New data from *Mars Global Surveyor*; moving toward Mars settlement.

Bioastronomy News:
Debate: "The Case for Life on Mars—What Does ALH84001 Hold?"

The NEO News:
Nano-rover goes to an asteroid aboard Japan's *Muses C*; sizing up the largest asteroids.

For more information on the Society's special-interest newsletters, call (626) 793-5100.

Charlene Anderson Promoted to Associate Director

Director of Publications Charlene Anderson has been named Associate Director of the Planetary Society. Serving as editor of *The Planetary Report* since our first issue in 1980, Anderson worked closely with Society co-founder Carl Sagan in developing the magazine's content and style and has been largely responsible for its success.

In recent years Anderson expanded the publications department to include the Society's special-interest newsletters and electronic publications. She has long been a champion of member involvement, seeking interactive opportunities in all our publications and activities.
—LDF

Moving Toward No Mortgage Payment

Thanks to member response to our special appeal last November, the Society made a principal-reduction payment of $150,000 on the mortgage for our historic headquarters building in Pasadena. We're striving to wipe out our remaining balance of $139,500 by next year; if you can help, please send a donation to the house fund.
—Lu Coffing, Financial Manager

In *A Philosopher Giving That Lecture on the Orrery in Which a Lamp Is Put in Place of the Sun*, Joseph Wright presents a synthesis of art, science, and philosophy. This painting, dated 1766, depicts a philosopher demonstrating a solar system model, called an orrery, to a rapt and thoughtful audience. The teacher has replaced the sphere that represents the Sun with an oil lamp, most likely to show how eclipses occur. Earth and the Moon are visible, perched on stems, immediately to the left of the Sun/lamp, while Saturn sits behind them, farther left.

Joseph Wright (1734–1797) has come to be recognized only recently as one of the great English painters of the 18th century. He spent most of his life working in the Midlands, far removed from London and popular contemporaries such as Reynolds and Gainsborough. As an artist, Wright had an interesting range. In addition to portraits and characters from literature, he painted scenes that lent themselves to a unique treatment of light, such as smithies and forges, Vesuvius, and fireworks. Wright's interest in scientific experiments produced two of the works for which he is best known: this one and *An Experiment on a Bird in the Air Pump.* Painting courtesy of the Derby Museums and Art Gallery, The Strand, Derby, England

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