Planetary scientists breathed a deep sigh of relief March 17. At 9:00 p.m. EDT, NASA’s MESSENGER spacecraft wrapped up a 15-minute firing of its thrusters, which slowed the probe just enough for Mercury’s gravity to snag it. This maneuver marked the end of a 4.9-billion-mile (7.9 billion kilometers) journey and the beginning of an orbital mission to explore the innermost planet expected to last at least 1 Earth year.

Anxiety soon gave way to exhilaration as photographs and other observations began streaming back from MESSENGER, which stands for MErcury Surface, Space ENvironment, GEochemistry, and Ranging. By the start of September, NASA’s latest planetary probe had returned more than 40,000 images and taken millions of measurements of Mercury’s topography and composition.

The flood of data produced the first two big surprises of the mission: Mercury’s surface composition differs markedly from what scientists expected, and the planet’s magnetic field doesn’t line up with its equator.

The new observations also gave scientists their first close-up looks at Mercury’s north and south polar regions. In each of the six previous flybys (three by Mariner 10 in the mid-1970s and three by MESSENGER in 2008–9), the spacecraft flew over the planet’s equator and managed only a few low-resolution photos of the poles. Initial results from orbit support the idea that water ice may lurk at the bottom of some deep polar craters.

MESSENGER orbits Mercury once every 12 hours on a highly elliptical path that brings it within 124 miles (200 km) of the surface at closest approach but swells to 9,440 miles (15,193 km) at maximum distance. The orbit’s low point comes above 60° north latitude, a position mission planners chose in part to allow detailed study of the giant Caloris impact basin, which spans 960 miles (1,550 km) and is Mercury’s largest surface feature. (Caloris remained in darkness early in the orbital mission; each night on Mercury lasts 88 Earth days.) Because the Sun’s gravity slowly alters the spacecraft’s orbit, MESSENGER occasionally has to fire its thrusters to keep on track.

The new images of the planet’s north polar region bring into focus what previously had appeared as blurred patches of light and dark. They reveal a broad expanse of volcanic plains that ranks among the largest on Mercury. These relatively smooth plains cover approximately 1.5 million square miles (4 million km²). Mission planners chose in part to allow detailed study of the giant Caloris impact basin, which spans 960 miles (1,550 km) and is Mercury’s largest surface feature. (Caloris remained in darkness early in the orbital mission; each night on Mercury lasts 88 Earth days.) Because the Sun’s gravity slowly alters the spacecraft’s orbit, MESSENGER occasionally has to fire its thrusters to keep on track.

The view from above
MESSENGER orbits Mercury once every 12 hours on a highly elliptical path that brings it within 124 miles (200 km) of the surface at closest approach but swells to 9,440 miles (15,193 km) at maximum distance. The orbit’s low point comes above 60° north latitude, a position

The MESSENGER spacecraft reveals Mercury to be a world with unexpected composition, an offset magnetic field, and permanently shadowed craters that may harbor ice.

by Richard Talcott

© 2013 Kalmbach Publishing Co. This material may not be reproduced in any form without permission from the publisher. www.Astronomy.com
This rugged landscape lies outside the giant Caloris Basin and stands as testament to the power of the impact that created it. The force unleashed by the Caloris impact scoured the surrounding surface and created these rough contours. \( \textit{NASA/JHUAPL/CIW} \)

"The crater \textit{Praxiteles} sports a prominent ring of mountain peaks roughly halfway from center to rim. Near the tops of these peaks lie several irregularly shaped depressions surrounded by bright material that may be sites of previous volcanic activity. \( \textit{NASA/JHUAPL/CIW} \)"

The spacecraft's laser altimeter, using the spacecraft's laser altimeter, reveals Mercury's northern latitudes like never before. The best previous view of this region came during the spacecraft's second flyby in October 2008, but it pales in contrast to an orbital mosaic. Note the many "ghost" craters near the image's center that formed when volcanic plains buried pre-existing craters. \( \textit{NASA/JHUAPL/CIW} \)

Using the spacecraft's laser altimeter, researchers think they represent water ice trapped at the bottoms of craters where the Sun never shines. However, some scientists suspect other ices or elemental sulfur could produce this radar signature.

The fact that astronomers even debate the existence of ice on the planet nearest the Sun points to Mercury's strangeness. After all, noontime temperatures on Mercury can reach 800° Farenheit (427° Celsius). But the planet's axis of rotation tips nearly perpendicular to its orbit around the Sun, so deep craters near the poles would remain in permanent shadow. Any ice that found its way to Mercury, presumably carried there by comets, could endure for billions of years. Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the planet's history, as some planetary scientists suspected.

Pits of confusion

During the course of the yearlong mission, MESSENGER's camera system will image most of Mercury's globe. A wide-angle camera will render the surface in black and white at resolutions approaching 33 feet (10 meters) per pixel. Mission scientists focus on regions of special interest with these high-resolution observations. One of their early targets is the bright, patchy deposits on some crater floors discovered during previous flyby missions. MESSENGER reveals them to be clusters of rimless, irregular pits ranging from several hundred feet to a few miles in diameter and concentrated near central peaks, rings of mountains, and crater rims. Diffuse halos of even brighter material surround the pits.

The etched appearance of these landforms is unlike anything we've seen before in the solar system," says Brett Denevi of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and a member of the imaging team. "We are still debating their origin, but they appear to be relatively young." Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the planet's history, as some planetary scientists suspected.

An off-kilter magnetic field

Volcanism at a planet's surface implies a molten interior during the period when the activity took place. But Mercury presents strong evidence that part of its core is still liquid. Among the inner worlds of the solar system, only Mercury and Earth have global magnetic fields. Scientists think both fields arise from electrical currents flowing in the outer part of the white at resolutions approaching 33 feet (10m) per pixel.

Mission scientists focus on regions of special interest with these high-resolution observations. One of their early targets is the bright, patchy deposits on some crater floors discovered during previous flyby missions. MESSENGER reveals them to be clusters of rimless, irregular pits ranging from several hundred feet to a few miles in diameter and concentrated near central peaks, rings of mountains, and crater rims. Diffuse halos of even brighter material surround the pits.

The etched appearance of these landforms is unlike anything we've seen before in the solar system," says Brett Denevi of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and a member of the imaging team. "We are still debating their origin, but they appear to be relatively young." Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the solar system's history, as some planetary scientists suspected.

An off-kilter magnetic field

Volcanism at a planet's surface implies a molten interior during the period when the activity took place. But Mercury presents strong evidence that part of its core is still liquid. Among the inner worlds of the solar system, only Mercury and Earth have global magnetic fields. Scientists think both fields arise from electrical currents flowing in the outer part of the white at resolutions approaching 33 feet (10m) per pixel.

Mission scientists focus on regions of special interest with these high-resolution observations. One of their early targets is the bright, patchy deposits on some crater floors discovered during previous flyby missions. MESSENGER reveals them to be clusters of rimless, irregular pits ranging from several hundred feet to a few miles in diameter and concentrated near central peaks, rings of mountains, and crater rims. Diffuse halos of even brighter material surround the pits.

The etched appearance of these landforms is unlike anything we've seen before in the solar system," says Brett Denevi of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and a member of the imaging team. "We are still debating their origin, but they appear to be relatively young." Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the solar system's history, as some planetary scientists suspected.

An off-kilter magnetic field

Volcanism at a planet's surface implies a molten interior during the period when the activity took place. But Mercury presents strong evidence that part of its core is still liquid. Among the inner worlds of the solar system, only Mercury and Earth have global magnetic fields. Scientists think both fields arise from electrical currents flowing in the outer part of the white at resolutions approaching 33 feet (10m) per pixel.

Mission scientists focus on regions of special interest with these high-resolution observations. One of their early targets is the bright, patchy deposits on some crater floors discovered during previous flyby missions. MESSENGER reveals them to be clusters of rimless, irregular pits ranging from several hundred feet to a few miles in diameter and concentrated near central peaks, rings of mountains, and crater rims. Diffuse halos of even brighter material surround the pits.

The etched appearance of these landforms is unlike anything we've seen before in the solar system," says Brett Denevi of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and a member of the imaging team. "We are still debating their origin, but they appear to be relatively young." Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the solar system's history, as some planetary scientists suspected.

An off-kilter magnetic field

Volcanism at a planet's surface implies a molten interior during the period when the activity took place. But Mercury presents strong evidence that part of its core is still liquid. Among the inner worlds of the solar system, only Mercury and Earth have global magnetic fields. Scientists think both fields arise from electrical currents flowing in the outer part of the white at resolutions approaching 33 feet (10m) per pixel.

Mission scientists focus on regions of special interest with these high-resolution observations. One of their early targets is the bright, patchy deposits on some crater floors discovered during previous flyby missions. MESSENGER reveals them to be clusters of rimless, irregular pits ranging from several hundred feet to a few miles in diameter and concentrated near central peaks, rings of mountains, and crater rims. Diffuse halos of even brighter material surround the pits.

The etched appearance of these landforms is unlike anything we've seen before in the solar system," says Brett Denevi of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and a member of the imaging team. "We are still debating their origin, but they appear to be relatively young." Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the solar system's history, as some planetary scientists suspected.

An off-kilter magnetic field

Volcanism at a planet's surface implies a molten interior during the period when the activity took place. But Mercury presents strong evidence that part of its core is still liquid. Among the inner worlds of the solar system, only Mercury and Earth have global magnetic fields. Scientists think both fields arise from electrical currents flowing in the outer part of the white at resolutions approaching 33 feet (10m) per pixel.

Mission scientists focus on regions of special interest with these high-resolution observations. One of their early targets is the bright, patchy deposits on some crater floors discovered during previous flyby missions. MESSENGER reveals them to be clusters of rimless, irregular pits ranging from several hundred feet to a few miles in diameter and concentrated near central peaks, rings of mountains, and crater rims. Diffuse halos of even brighter material surround the pits.

The etched appearance of these landforms is unlike anything we've seen before in the solar system," says Brett Denevi of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and a member of the imaging team. "We are still debating their origin, but they appear to be relatively young." Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the solar system's history, as some planetary scientists suspected.

An off-kilter magnetic field

Volcanism at a planet's surface implies a molten interior during the period when the activity took place. But Mercury presents strong evidence that part of its core is still liquid. Among the inner worlds of the solar system, only Mercury and Earth have global magnetic fields. Scientists think both fields arise from electrical currents flowing in the outer part of the white at resolutions approaching 33 feet (10m) per pixel.

Mission scientists focus on regions of special interest with these high-resolution observations. One of their early targets is the bright, patchy deposits on some crater floors discovered during previous flyby missions. MESSENGER reveals them to be clusters of rimless, irregular pits ranging from several hundred feet to a few miles in diameter and concentrated near central peaks, rings of mountains, and crater rims. Diffuse halos of even brighter material surround the pits.

The etched appearance of these landforms is unlike anything we've seen before in the solar system," says Brett Denevi of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and a member of the imaging team. "We are still debating their origin, but they appear to be relatively young." Some team members suspect they are volcanic vents, implying that volcanic activity on Mercury didn't die out early in the solar system's history, as some planetary scientists suspected.
The bizarre field also affects how Mercury interacts with charged particles in the solar wind. The magnetic field lines near the planet’s south pole remain open to interplanetary space over a much broader area than those in the north. This means solar-wind particles hit the south polar regions far more frequently than the northern ones. Because such impacts contribute to the planet’s tenuous atmosphere and to the “space weathering” that darkens surface material over time, Solomon thinks MESSENGER ultimately will see south-south asymmetries in these as well. Mercury’s magnetic field originates in the core, which is a decidedly strange place. Earth’s core contains approximately one-third of our planet’s total mass and stretches from the center to a bit over halfway to the surface. But Mercury’s iron-rich core holds at least 60 percent of the planet’s mass and extends 75 percent of the way from the center to the surface. Understanding why Mercury possesses such a huge core is one of the key goals of MESSENGER’s mission.

A compositional conundrum

The other big surprise in MESSENGER’s tidal wave of data is how different Mercury’s surface composition is from Earth and the Moon — and from what scientists expected. The spacecraft carries two instruments to measure the abundance of elements on the planet. The X-ray Spectrometer works by fluorescence, the same process that causes a black-light poster to glow when illuminated by ultraviolet radiation. The spectrometer measures X-rays given off by atoms at the planet’s surface when they get hit by X-rays emanating from the Sun. Because our star has been fairly active in 2011, scientists have a lot of data to work with.

The Gamma-ray and Neutron Spectrometer (GRNS) measures energetic gamma rays. When cosmic rays coming from outside the solar system strike Mercury’s surface, they liberate high-energy neutrons that hit neighboring atoms and cause them to emit gamma rays. The spectrum of gamma rays acts like a DNA fingerprint to identify individual elements. The GRNS also detects gamma rays from the radioactive decay of potassium, thorium, and uranium.

MESSENGER’s spectrometers measured Mercury’s composition and found that the planet contains far more magnesium and far less aluminum than the surface rocks of either the Moon or Earth. On the Moon, aluminum floated to the surface early in lunar history when the satellite was largely molten. Earth experienced a smaller aluminum enhancement when rocks in its mantle partially melted. Mercury must have undergone widespread melting early on, too, but it shows little aluminum for the effort.

The plans of Mercury also hold unexpectedly large concentrations of sodium and sulfur but low amounts of iron and titanium. Sulfur, which is up to 10 times more abundant on Mercury than on the Moon or Earth, could have contributed to explosive volcanic activity earlier in Mercury’s history. Planetary geologist Larry Nittler of the Carnegie Institution of Washington admits that initial results from the spectrometers remain baffling, but they say point to the building blocks of Mercury being different than those of Earth or the Moon.

MESSENGER’s most startling abundance measurements so far have been those of potassium and thorium made by the GRNS. The ratio of potassium to thorium on Mercury is higher than that on any other inner planet. Potassium is a volatile element, which means that it vaporizes at a relatively low temperature, while thorium is the opposite. Because Mercury lies so close to the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.

An unknown origin

The findings cast doubt on some of the ideas proposed to explain Mercury’s origin. Recall that the planet has an inordinately large iron core. Some scientists suggest it got that way simply because of its location. In this scenario, the innermost planet accreted out of the same material in the solar nebula as the Sun’s heat, scientists expected it to have a lower proportion of potassium.