First Look at Mercury

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Why go to Mercury? Who needs it? A planetary scientist tells what the voyage is all about

All of us living today have the privilege of witnessing man reaching out for the first time to examine objects that were nothing more than mysterious points of light to his predecessors. That first look, the reaching out beyond his own planet, is an opportunity offered to just a few generations in all of man's history. I feel that's something to remember when faced by depressing news in the morning newspaper and the evening television program.

The year 1973, for example, in most Americans' minds conjures up images of Watergate scandals, war in the Middle East, the energy crisis, and rampant inflation. Yet it's useful for us to stop and consider that 1973 also was the 500th anniversary of the birth of Copernicus, who first organized man's thoughts about the movements of planets into a rational system. The year 1973 marked the completion of the first half-millennium of the modern age, and 1973—fittingly—was also accompanied by intensive space exploration by Earthlings with unmanned probes to Jupiter, Mars, Venus, and Mercury.

Mariner 10 was launched to Mercury by way of Venus on November 3, 1973. It was not the first probe to visit Venus. Both the United States and the Soviet Union previously have sent probes to that mysterious, cloud-shrouded planet. However, Mariner 10 was the first to photographically explore the close-up appearance of the planet, and did so both in visible and in ultraviolet light. And Mariner 10 was the first probe of any kind to penetrate interplanetary space beyond the orbit of Venus and to achieve a close look at the planet Mercury.

Why go to Mercury? Who needs it? There basically are two kinds of reasons. The first is simple and profound and difficult to quantify: The very act of exploration is a positive, cultural activity. No one knows what is going to be found. Finding out what Mercury, what Mars, or what the moon is really like, enlarges the consciousness of all the people who partake of that new reality. TV pictures are of special importance because they provide a way both for the scientist to discover features and concepts he could not have imagined and for the public to directly appreciate and participate in the exploration of a new world.

But there are more specific scientific objectives as well. For Mercury, the basic—and anomalous—scientific fact is that it is a very dense planet: It contains a great amount of mass for its size. Mercury is a small object, somewhat larger than the moon, but not as large as Mars. Yet, it is as dense as the earth. Thus Mercury, like the earth, must have a large amount of iron in its total planetary composition. Indeed, some years ago it was computed that if Mercury were differentiated chemically the way the earth is, into an iron core and a silicate mantle, Mercury's core would be three-quarters the diameter of the entire planet! (Mercury is 4,900 kilometers in diameter.) The silicate mantle would be a shell merely 500 or 600 kilometers thick. On the other hand, Mercury need not necessarily be differentiated like the earth. Conceivably, it could be composed of silicate and iron phases scattered uniformly throughout its entire body.

In addition to understanding its chemical and physical state, the other paramount question about Mercury is what can be inferred about its history from what can be seen upon its surface. Are there still topographic features that have survived from the time of planetary accretion or early heavy impact? Or have the actions of subsequent atmospheric phenomena or other processes erased those early topographic forms?

So the guiding objectives of Mariner 10 as a probe, not just for the imaging experiment but for all the scientific experiments, were developed to address two kinds of questions: "What kind of planet is Mercury?" and "What has been its history?" I think we have been rewarded handsomely; rather good answers to both questions have been obtained on the very first exploratory attempt. Of course there is still much scientific debate, but it encompasses a much narrower range of possibilities than might have been

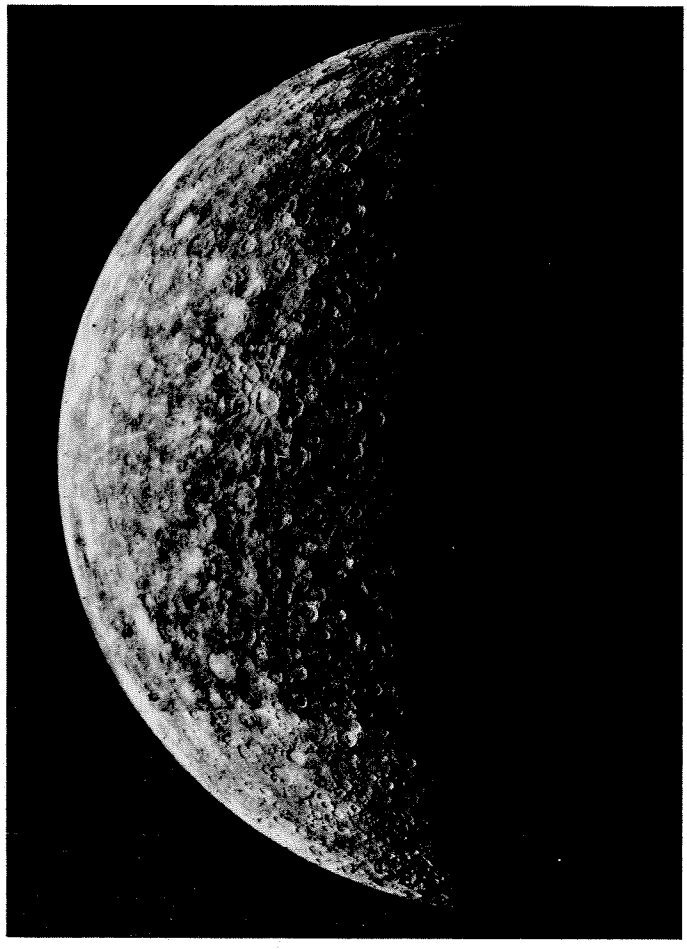
the case if Mariner 10 had been a less capable robot.

Before even designing a spacecraft to fly to Mercury, a very large problem had to be overcome. It takes a great deal of rocket thrust to go directly from the orbit of the earth to the orbit of Mercury. A launch vehicle larger than the rocket that launched the Gemini astronauts (Titan) would be needed—far larger than any used previously by the United States for the unmanned probes to Mars.

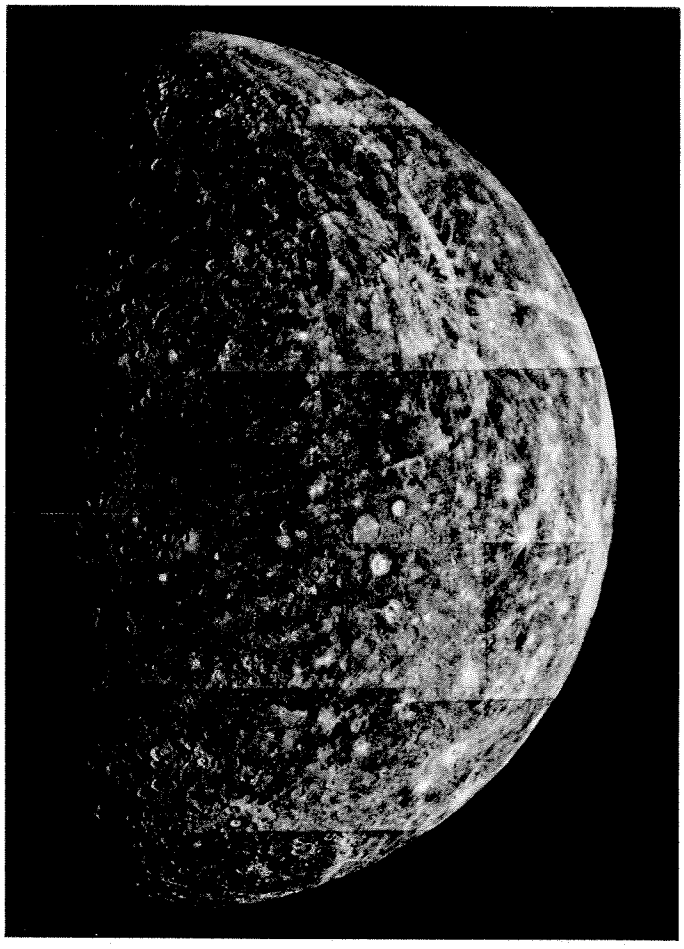
Fortunately for the exploration of Mercury, a clever trick had been thought up some years ago. If a probe passes close to one planet, it can be caught up in a gravitational tug-of-war between the sun and that planet, with the result that the probe is accelerated either in closer to the sun or further outward. Thus, in November 1973, the same kind of rocket (Atlas Centaur) previously used to go to Mars launched Mariner 10 toward Venus. There, a "target" near Venus only 20 miles in diameter was passed at a precise time, and Mariner 10 was diverted by the sun's gravitational pull onto a close passage of Mercury. Had it not been for this energy conservation scheme, there would have been no Mercury flight at all for many, many years, I'm sure. In addition, going by Venus along the way made possible the first exciting photographic exploration of that planet (*E&S*—March-April).

Despite many difficulties, which kept everybody constantly inventing new ways to accomplish old objectives, by the end of March, Mariner 10 approached Mercury and took the first picture about a week before encounter. Fuzzy as it was, it already was slightly better than the best previous pictures taken from the ground. Then the Mariner 10 view rapidly increased in resolution to reveal a heavily cratered surface similar to parts of the lunar surface. Indeed, it looked as though Mariner 10 were encountering the back side of the moon, which exhibits very little of the smooth volcanic plains called maria.

On the other hand, after passing by the closest approach to Mercury on the dark side (below, left) and emerging on the far side, viewing along the terminator, a totally different panorama was seen (below). There the landscape is dominated by vast volcanic plains, flooding large circular

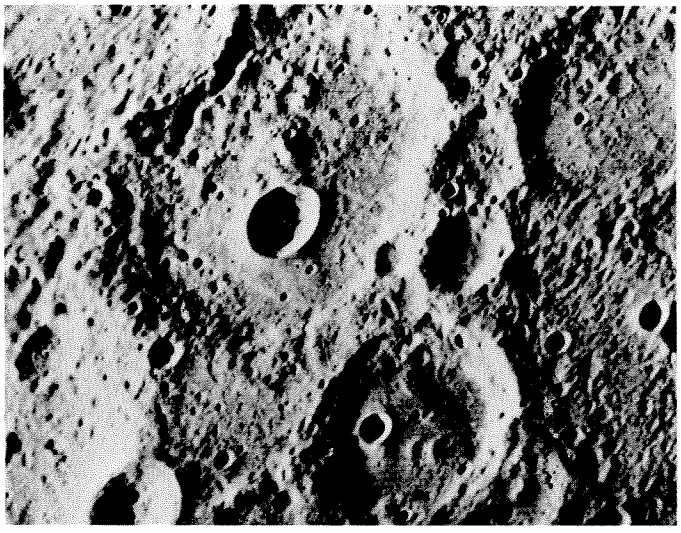


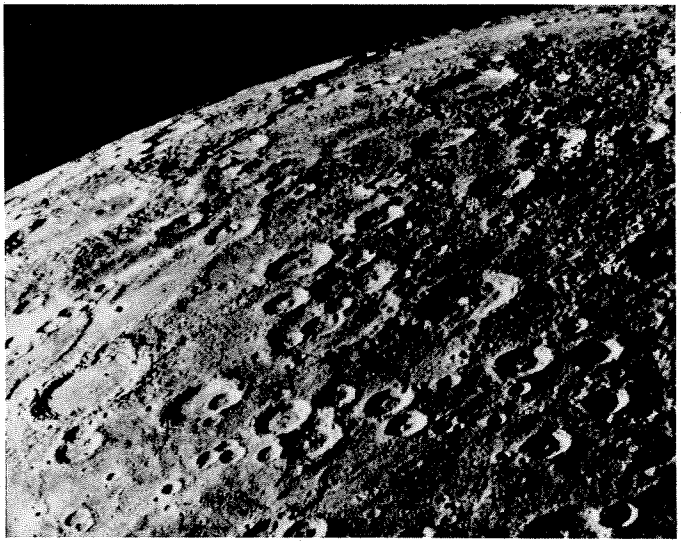
Eighteen pictures, taken at 42-second intervals by Mariner 10's two TV cameras, were computer-enhanced at JPL and fashioned into this photomosaic of Mercury. The pictures were taken on March 29 during a 13-minute period when Mariner was 200,000 km and six hours away from Mercury and approaching the planet. About two-thirds of this portion of Mercury is in the southern hemisphere. The cratered surface is somewhat similar to that of the moon, and the largest craters are about 200 km in diameter.



Taken from a distance of about 210,000 km, this photomosaic of Mercury was constructed of 18 photos taken at 42-second intervals six hours after Mariner 10 flew past the planet. The north pole is at the top, and the equator extends from the left to right about two-thirds down from the top. A large circular basin, about 1,300 km in diameter, is emerging from the day-night terminator at left center. Bright rayed craters are prominent in this view of Mercury. One such ray seems to join in both east-west and north-south directions.

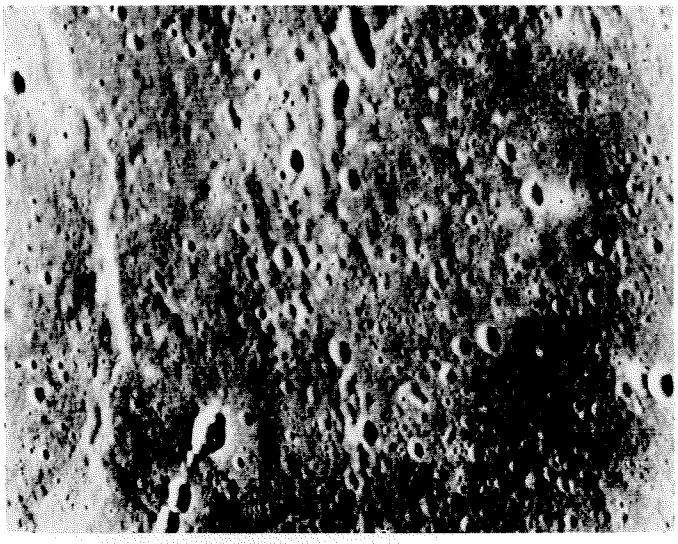
Here the surface of Mercury shows a fresh new crater in the center of an older crater basin. The newer crater (almost centered) is about 12 km across. The picture, which covers an area 130 by 170 km, was taken from a distance of about 20,700 km.

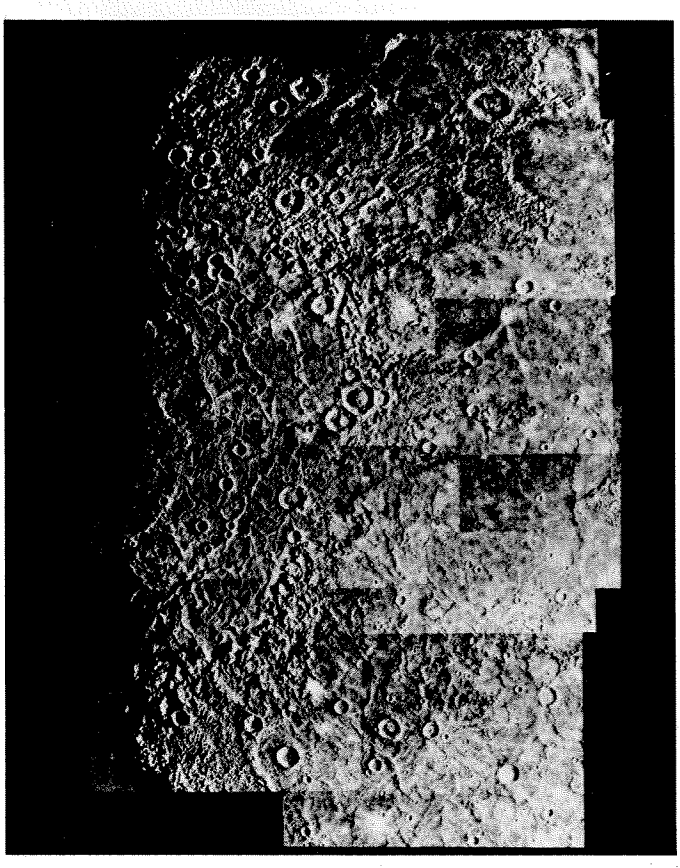




This view of Mercury's northern limb shows a prominent east-facing scarp extending from the limb near the middle of the photo southward for hundreds of kilometers. The linear dimension along the bottom is about 580 km, and the photograph was taken at a distance of about 77,800 km.

Revealing craters as small as 150 meters, this is one of the highest resolution pictures obtained by Mariner 10. The picture is taken from a distance of about 5,900 km and shows an area about 50 by 40 km. In spite of numerous craters in various stages of degradation, the surface is relatively level, contrasting with the abundant relief seen in some views on the opposite side of the planet. The long, narrow area of hills and scarps to the left resembles ridges in the mare material of the earth's moon.





The largest structural feature discovered on Mercury by Mariner 10 is seen in the left half of this photomosaic. It is a ring basin 1,300 km in diameter, bounded by mountains that rise as high as 2 km, and with a floor that is intensely disrupted by fractures and ridges. Similar in size and appearance to the moon's Imbrium Basin, this feature was undoubtedly created by the impact of a body at least tens of kilometers in diameter. Scientists have provisionally named this basin "Caloris" (or hot basin) because of its position near one of the subsolar points when the planet is nearest the sun.

basins, very similar to the lunar mare. Mercury exhibits also the strange asymmetry of the moon (and Mars and earth)—that is, the two hemispheres exhibit very different kinds of topographic features.

Thus the surface of Mercury resembles that of the moon in surprisingly great detail despite the great bulk density differences (3.3 vs 5.4 gms/cm^3). What does this have to say about the kind of planet Mercury is and about its history? The fact that there are huge basins that have been flooded with volcanic material, as on the moon, implies that Mercury must resemble the moon down to some appreciable depth—at least the depth from which these volcanic materials originated. Thus Mercury is lunar-like presumably for hundreds of kilometers down. On the other hand, it cannot be of lunar-like silicate composition for more than 500 or 600 km depth and still maintain its gross, earth-like density. Hence, the most plausible explanation of the overall appearance of Mercury as seen in the Mariner 10 pictures is that it is a chemically differentiated planet with a lunar-like silicate zone for the outer 500 or 600 km and a very large iron core for the great bulk of its interior.

The probability of an iron core is also suggested independently by the magnetometer, plasma probe, and charge-particle detectors aboard Mariner 10, which recorded substantial disturbances as the spacecraft passed close to Mercury, of much more magnitude than any experienced in the vicinity of Venus. Conceivably Mercury may not only resemble the earth in its iron core, but may exhibit a very small but permanent earth-like dipole magnetic field as well, although this is still a point requiring further investigation. Thus, the view from Mariner 10 suggests that Mercury is a unique planet, like the moon on the outside but like the earth on the inside.

What has been its history? What can we say, from the pictures, about how Mercury formed and evolved subsequently? First of all, the heavily cratered surfaces, especially as seen on the incoming leg of the trajectory, record topographic forms that could have been created only very early in the history of the solar system, perhaps four billion years ago or more (before any rocks now exposed on the surface of the earth were formed).

Obviously, there have been no subsequent surface processes sufficient to destroy them over that entire time period.

In particular, we can rule out the existence of any tangible atmosphere throughout almost all of Mercury's history. By comparison, even Mars's thin atmosphere is sufficient to modify the appearance of recent impact craters. Secondly, if Mercury is indeed differentiated chemically, that process of separation of the iron phase from the silicates must have taken place very early in its formation, perhaps even during the process of accretion from the solar nebula.

This possibility is in distinction to one traditional view that the earth, at least, accumulated homogeneously, then underwent planetary differentiation later. In the case of Mercury, homogeneous accumulation does not seem to be indicated. The Mariner 10 results, after more analysis, may provide insight into the very early history of the earth itself. Thus, Mariner 10's long reach across space, which magnified by a factor of 5,000 our view of the surface of Mercury, may also carry us back in time, perhaps back further than any previous photographic mission to the planets.

What happens to Mariner 10 after passing Mercury? A very surprising thing! Mariner 10 is in an orbit about the sun that returns to the vicinity of Mercury every 176 days, a duration of exactly two Mercurian years. It will re-encounter the vicinity of the planet every two Mercurian years. The second encounter took place September 21 of this year when we made pictures over the south polar regions of the planet and recorded those areas that were badly foreshortened in the first pass by the planet. It is even possible that some scientific measurements can be acquired during the third passage by Mercury, another 176 days later (March 1975). Not only has man created another minor planet with the mission of Mariner 10, but he has created one that has the peculiar property of being in a resonant orbit with planet Mercury.

Thus, Mariner 10 highlights an unusual period in man's history, in his reaching out to understand his planetary environment. The voyage of Mariner 10 has constituted a very appropriate way to celebrate the first half-millennium of the existence of modern scientific thought, the 500th anniversary of Copernicus' birth. □