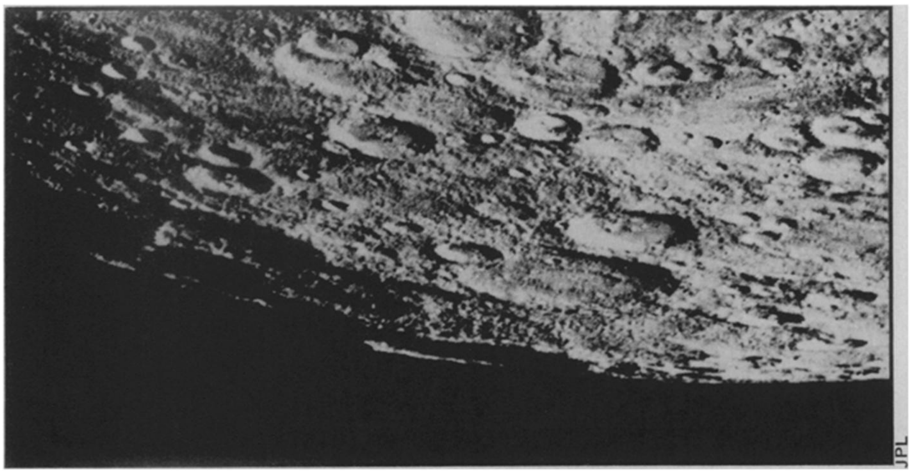
Mercury: Scarps, massive impact craters and a compressed core



Mariner 10 view of south polar region of Mercury: Very much a world of its own.

Less than six months after Mariner 10 became earth's first emissary to Mercury, it also became the second. Passing less than 48,000 kilometers from the planet on Sept. 21, the spacecraft confirmed the finding of its initial visit: that Mercury, far from being a dull, run-of-the-mill ball of rock, is very much a world of its own.

Following a space trek of more than 560 million kilometers, including a full trip around the sun since last March's Mercury encounter, Mariner swooped this time between the planet and the sun, dipping low to photograph the never-before-seen south pole. In addition, its cameras scanned across the full expanse of the southern sunlit face, providing images to link the incoming and outgoing pictures gathered during the previous darkside pass. "We now have a very good topographic and geologic tie," says Robert Strom of the University of Arizona, "between the two sides of the planet."

Establishing such continuity is important not only for mapping and other general studies but also for learning about the planet's regional characteristics. Mars, for example, appeared to Mariners 6 and 7 as a world completely dominated by seemingly endless fields of meteor impact craters—until Mariner 9, after waiting out a month-long dust storm, revealed a series of huge volcanic basins, a vast canyon that would span the United States and apparent erosion features looking for all the world like ancient dry riverbeds. By the same token the Soviet Lunik 3 surprised scientists by revealing the far greater concentrations of craters on the far side of the moon.

Mercury has its own special features—huge scarps, or cliffs, thrust upward by irresistible compression of the planet's crust and virtually unknown on either the moon or Mars. Planetologists have been awaiting Mariner's revisit to find out whether the scarps are only an occasional phenomenon or exist over most of the surface of this world that otherwise seems strangely to lack any signs of planetwide geologic activity. More than half of the planet is still unphotographed, but enough has now been seen that Strom feels confident in saying of the scarps, "they are global in scope."

But, do they evenly cover the surface, or do they give Mercury a puzzling asymmetry, a difference between one face and the other, such as is found on Mars, the moon, even the earth? The real answer must wait until computers can assemble the photographs into montages covering vast areas of the surface, but there are signs of asymmetries even in preliminary viewings. Smooth, volcanically filled in plains, for example, seem to exist more around the newly seen south pole than at lower latitudes, according to NASA's Donald B. Gault, a member of the huge team of experimenters studying the photographs. If the scarps' detailed distribution is not yet known, the fact that they at least seem to occur generally across the planet nonetheless offers some insight into the nature of Mercury. The compression that caused them, says California Institute of Technology's Bruce Murray, leader of the TV team, is a likely consequence of the shrinking of the planet's core, probably an iron one, creating wrinkles like those that form on a deflating balloon.

The core, says Strom, is probably a big one. Mercury's overall density of 5.45 (almost that of earth) and lightweight, apparently nonmetallic crust, suggests that the core may include as much as 70 percent of the planet's mass, compressed into a still ponderous 50 percent of its volume. Earth's core, by comparison, accounts for less than a sixth of the volume of the planet.

But among all the scarps, plains and craters, there is one feature on Mercury that stands out, one of the greatest single markings on any world yet studied by man: the titanic Caloris Basin. Discovered during the first flyby, the giant crater is some 1,300 miles across, straddling the Mercurian twilight zone about 30 degrees north of the equator. Gault says the gargantuan object that produced it smote the planet with a trillion times the energy that created gigantic Meteor Crater in Arizona. And possibly coupled with it is another striking feature.

The TV team calls it "the weird terrain." Hilly, corrugated, raked with grooves, yet mysteriously smooth between the rough spots, the peculiar marking has been seen only in one area of Mercury—a part directly through the planet from Caloris Basin. Researchers have searched the preliminary versions of the second-encounter photos for more, but so far to no avail. Similar terrain has been found on earth's moon, but again, only opposite two of the largest lunar basins, Mare Imbrium and Mare Orientale.

Gault theorizes that the unusual landscape could have been produced by shockwaves resounding all the way through the planet from the impact that caused the basin, possibly reverberating along the channel between the core and crust. It is also possible, but unlikely, he says, that it is a volcanic feature, born of internal forces rather than a world-shaking blow. The most exotic proposal is that the impact that formed Caloris ejected material so violently that it flew around the planet in all directions, finally touching down 180 degrees away. Surveyors, Lunar Orbiters, and Apollos have failed to explain the lunar patches, however, so Mercury's weird terrain may remain unexplained for some time.

One of the biggest surprises about the first flyby was the discovery that Mercury makes its presence felt in the space around it. A magnetic field was weak but present where none was expected, and the spacecraft reported the equally unanticipated presence of rich streams of high-energy electrons flowing along the field lines. Prior to the second encounter, Mariner scientists were even more certain that they would find nothing; the spacecraft at its closest would be more than 60 times farther from the planet than it was the first time. It is still too early to be sure—Norman Ness of NASA has just started looking at his magnetometer data—but plasma researcher Al Lazarus of Massachusetts Institute of Technology reports fluctuating streams of the same high-energy electrons, this time on the upstream or

Scarp runs 185 miles across surface.

sun side of Mercury. If, as it appears at first glance, the planet's influence is present there, it may show up in the magnetic field as well. The main goal of the second encounter, however, was the pictures. Next March, the third and final pass, on the planet's darkside again, will be largely devoted to the infrared, ultraviolet and other instruments, looking from as close as 2,360 kilometers. There is some concern about whether Mariner's reserve of control gas is adequate for the journey—"I think it'll have some of the element of 'the Perils of Pauline,' " says Project Manager Gene Giberson—but officials are cautiously optimistic. "As far as I'm concerned," says Program Manager William Cunningham, "we're on our way to 'Mercury 3' right now." □

'Jupiter effect': Mixed reaction

The planets of the solar system are moving surely and inevitably toward a configuration that happens only once in 179 years. In 1982 there will come a moment when all the planets are in line with each other on the same side of the sun.

A newly published book, *The Jupiter Effect* by John Gribbin and Stephen Plagemann (New York: Walker and Co., 1974), foresees disastrous effects for that planetary imbalance. Gribbin and Plagemann predict increased seismic activity in the years around 1982 and specifically a major earthquake for the Los Angeles area.

Due to stories about it in the past two weeks by United Press International and Newsweek, the Jupiter effect theory is getting considerable public attention, including a formal query from a U.S. Senator. But the theory is receiving, at best, mixed reviews by scientists.

The two authors propose this chain of events: The planets exert tidal forces on the sun, and with all planets lined up on the same side of the sun such forces reach a maximum. The maximum force triggers an overabundance of sunspots. More sunspots mean more solar particles reaching the earth's upper atmosphere. The particles trigger unusual movements of large air masses. These movements affect the earth's rate

The Colombo Connection: How Mariner was brought back

"Looking back on things like this, you kind of kick yourself," says Joseph G. Beerer, "but sometimes you just can't see the forest for the trees." He wasn't the only one. In 1970, Beerer was the trajectory analyst helping to plan Mariner 10's flight past Venus and Mercury. His gentle self-chastisement is for his failure to realize the significance of a number buried in a computer printout on his desk, showing that Mariner could easily be aimed to pass close to Mercury two, three, and a virtually infinite number of times. And almost for free.

The math was easy. It would almost inevitably have occurred to someone sooner or later. As it happened the brainstorm was that of Italian astrophysicist Giuseppe Colombo, whose work in 1966 had helped to explain the newly discovered 3:2 ratio between Mercury's rotational and orbital periods.

Early in February of 1970, a group of scientists met at the California Institute of Technology to discuss Mercury, including the upcoming flyby. The launch date had already been chosen to minimize the energy required for the flight, and an arrival date had been picked to give a proper lighting angle for photography on the single visit that was then planned. Mission officials had also decided because of some of the experiments to aim for the planet's "dual-occultation zone," a region where Mercury would block both the earth and the sun from the spacecraft's view. Even with these stipulations, however, there was a range of available aiming points, each of which would take Mariner 10 into a different solar orbit after leaving Mercury.

It was at this meeting that Colombo tugged on the jacket of Caltech's Bruce Murray, who would be Mariner's chief picture analyst, and exclaimed, "The spacecraft will return! The spacecraft will return!" Queried by Murray, Colombo pointed out that among the range of possible post-Mercury solar orbits there seemed to be one with a period of 176 days, exactly twice the 88-day period of the planet. Couldn't this orbit be fine-tuned so that every two trips around the sun Mercury would find the spacecraft waiting for it?

Murray asked Beerer to find out. Sure enough, already on Beerer's desk was a computer listing of alternatives including one in which Mariner would move around the sun an average of 2.04 degrees per day. Divided into the number of days in a year, it came out just right for repeated encounters—extra flybys for free.

Well, not quite. A few changes had to be made in the spacecraft design, and time was short since the contracts with the builder (Boeing) had to be signed that autumn. Valves were adapted from Apollo so that Mariner's engine could be restarted the required number of times. Pioneer contributed a larger tank to hold an increased amount of control gas. Solar panels had to be made movable for better cooling, and an antenna was pivoted so that it could aim at earth while the spacecraft was behind the sun between encounters.

And it all had to be done while adding neither cost nor weight. Fortunately (and atypically), Mariner 10 came in about $750,000 under budget, thanks largely to its NASA project, program and spacecraft managers, respectively, Gene Giberson, William Cunningham and John Casani, and the spacecraft program manager at Boeing, Edward Czarnecki. The weight miraculously took care of itself: The conservatively rated Atlas-Centaur rocket turned out to be able to handle the load.

The cost of keeping data analysts and others around for the second encounter had added only about two percent to Mariner 10's $98 million budget, with another 1.7 percent for "Mercury 3" next March 16, but that comes out of more recent budgets. Altogether, the Colombo Connection, with Beerer, Giberson, Cunningham and colleagues, has been one of the better investments in NASA's planetary research program. □