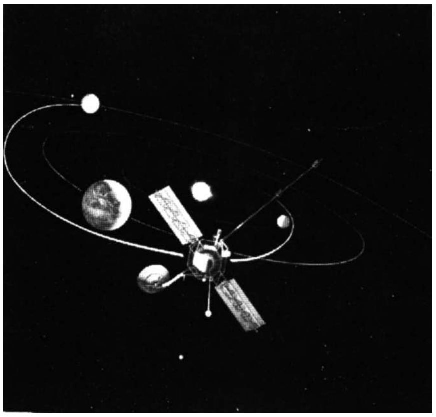


MARINER VENUS / MERCURY 1973

STATUS BULLETIN

MARINER 10 PICTURES OF MERCURY; SECOND ENCOUNTER PLANNED

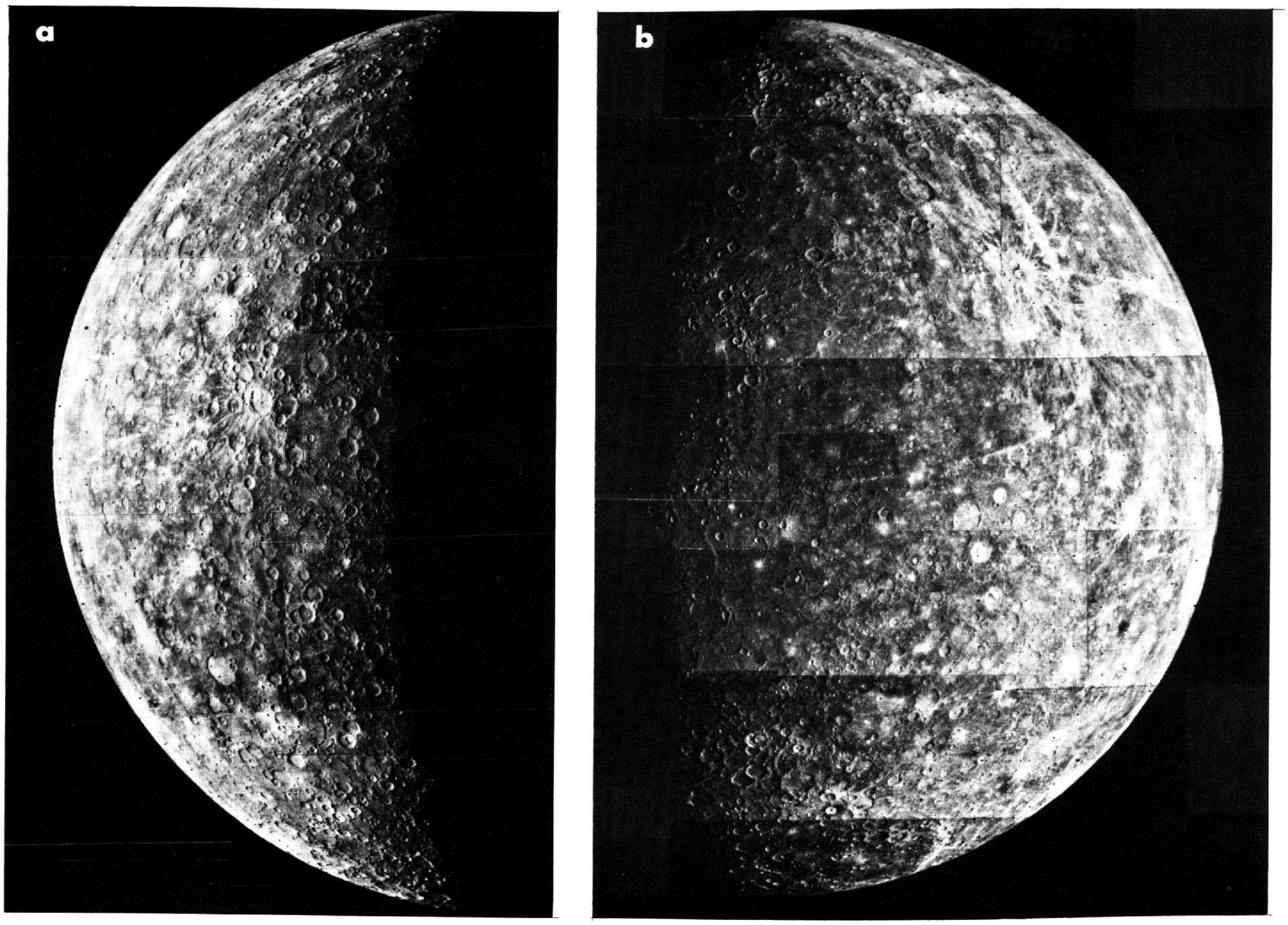


Fig. 1. (a) Photomosaic of Mercury made from nine computer-enhanced pictures taken at 234,000 km, 6 hours before closest approach to the planet. North is at the top, and the Sun's illumination is from the left. The evening terminator is at about 20° W longitude, and the bright limb is at 110 °W longitude. This part of Mercury is heavily cratered, the craters ranging in size up to almost 200 km. Apparently the freshest craters are those with bright rays, for example, the bright crater (diameter about 40 km) near the center of the picture. This picture and (b) show the whole of the illuminated portion of the planet; adjoining areas lie along the bright limb of both pictures. (b) Twelve computer-enhanced pictures taken at 210,000 km 5 1/2 hours after closest approach form this photomosaic. Half of a 1300-km multiringed basin appears near the center of the disk on the terminator. The inner portion and parts of the surrounding area are relatively poorly cratered plains materials similar in aspect to the lunar mare units. Several craters with bright rays are evident; a bright ray pattern, which appears to connect several young craters, forms a smooth hyperbolic curve. The North Pole is at the top, and the Equator extends from left to right about two-thirds of the way down the photo. The bright limb is at 110°W, and the terminator is at 200°W.

MARINER VENUS/MERCURY 1973 PROJECT OFFICE
Jet Propulsion Labratory California Institute of Technology
National Areonautics and Space Administration
Pasadena, California

3 May 1974

BULLETIN NO. 29

Mercury has a heavily cratered surface containing basins up to at least 1300 kilometers diameter flooded with mare-like material. Many features are closely similar to those on the Moon, but significant structural differences exist. Major chemical differentiation before termination of accretion is implied. This article was published in Science, Vol. 184, 26 April 1974.

Mariner 10 began photographing Mercury on 23 March 1974, from a distance of 5,400,000 km. Intermittent picture taking continued daily until 28 March when nearly continuous photographic operations were initiated to include the period of closest encounter on 29 March. Periodic photographic operations continued until 3 April when the probe was 3,500,000 km past Mercury. More than 2000 television frames were transmitted from the twin high-resolution cameras described in Bulletin No. 17.

As a consequence of the great public interest in closeup pictures of this previously unexplored planet, we think it is desirable, even at this early time, to present a very brief description and preliminary interpretation of those images initially available in hard copy. An extensive preliminary report is planned after the entire data set has been examined; that report and reports on the six other experiments aboard Mariner 10 will be issued later.

The major landforms on Mercury observed by Mariner 10 are basins, craters, scarps, ridges, and plains (Fig. 1). Morphologically these features strongly resemble analogous landforms on the Moon. Where the plains are absent, overlapping craters and basins form rugged terrain. The plains materials have many of the characteristics of the lunar maria and have been cratered to approximately the same degree. This twofold division of the surface morphology of Mercury is strikingly similar to that on the Moon.

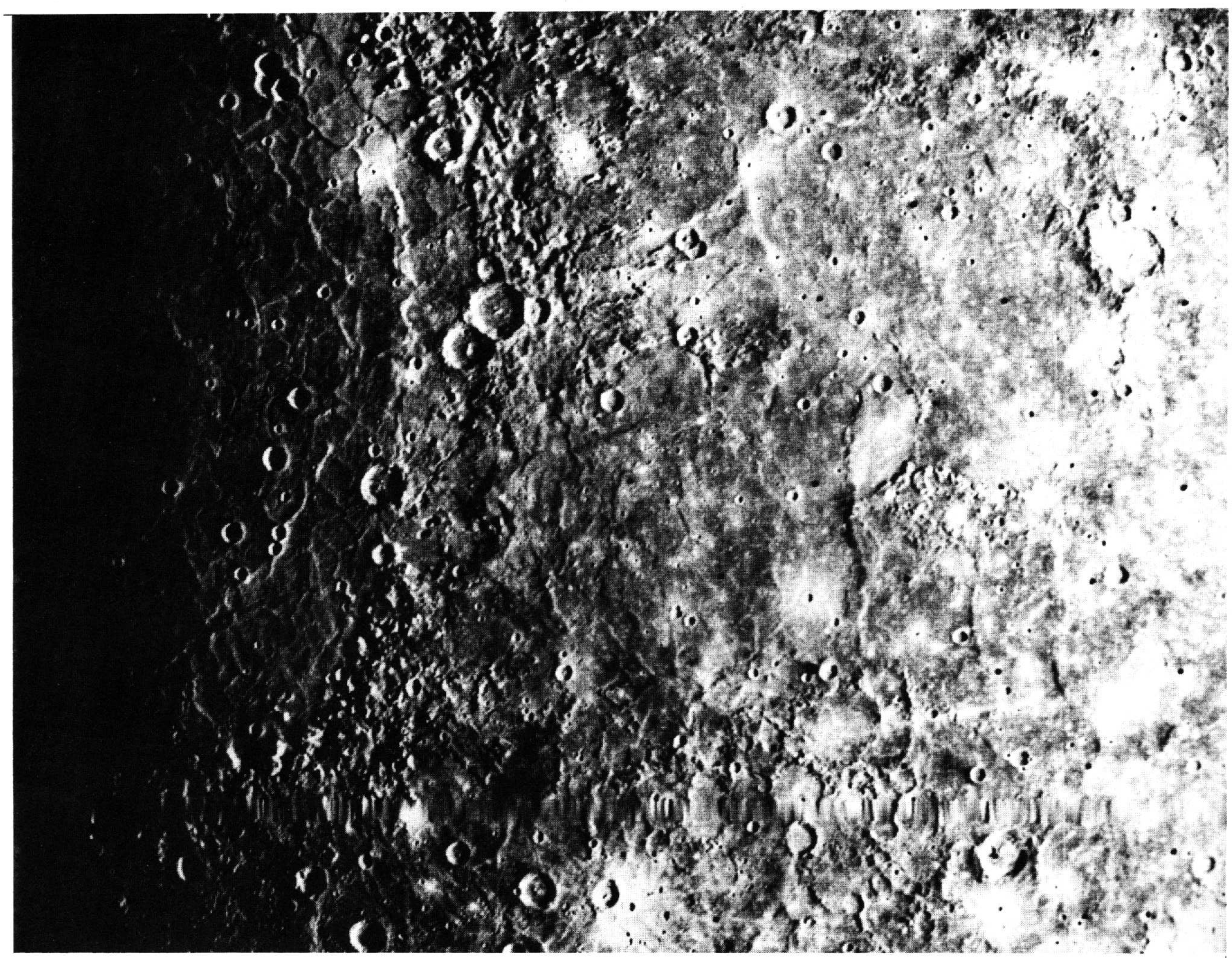


Fig. 2. Close-up view of one-half of the 1300-km circular basin shown in Fig. 1b. The other half is hidden beyond the terminator to the left. Hills and valleys extend in a radial fashion outward from the main ring. Interior of the large basin is completely flooded by plains materials; adjacent lowlands are also partially flooded, and superimposed on the plains are bowl-shaped craters. Wrinkle ridges are abundant on the plains materials. The area shown is 1600 km from the top to the bottom of the picture. The Sun's illumination is from the right. Blurred lines extending across the picture near the bottom are missing data lines that have been filled in by the computer.

The largest basin observed so far on Mercury is centered at ~ 195°W,30N°(Fig. 2) and has many of the characteristics of the lunar Imbrium basin. Numerous smaller basins also are evident, grading from sharply defined to barely discernible; some have two concentric rings. Craters range in size downward from the dimensions of basins (Fig. 3, a and b) to the limits of detectability on the highest-resolution photographs (Fig. 3c). Extensive ray systems are present around some bright craters. The plains materials have filled and embayed the larger basins and adjacent lowlands (Fig. 2). Smooth material morphologically like Lunar mare in some cases fills ancient craters without evidence of external origin (Fig. 4). As on the Moon, a local source of volcanic material is suggested. Numerous wrinkle ridges similar to those on the lunar maria have formed within the plains (Figs. 2 and 3c). A volcanic origin for much of this material is implied.

Prominent structural features on Mercury include irregular scarps which are up to 1 km high, extend for hundreds of kilometers, and cut across large craters and intercrater areas (Fig. 3a). Similar features are absent on the Moon. In addition, the paucity of straight rilles and graben on Mercury suggests a major difference in structural style between Mercury and the Moon. No features suggestive of either Earth-like plate tectonics or large-scale tensional faulting in the crust have been recognized so far.

The Mariner 10 photographs of Mercury, combined with previous studies of the terrestrial planets, suggest four preliminary conclusions.

1) Extensive flooding by rock materials at least grossly similar to those of the lunar maria has occurred on Mercury. The large horizontal scale of such features implies a silicate composition (density ~ 3) for the entire outer regions of the planet, not just the upper centimeters or meters as is indicated directly by remote optical, infrared, and radio measurements. Yet the mean planetary density of 5.5 g/cm^3 requires that very much denser material must occur at depth, very probably in the form of a large iron core. Thus Mercury is a chemically differentiated planet.

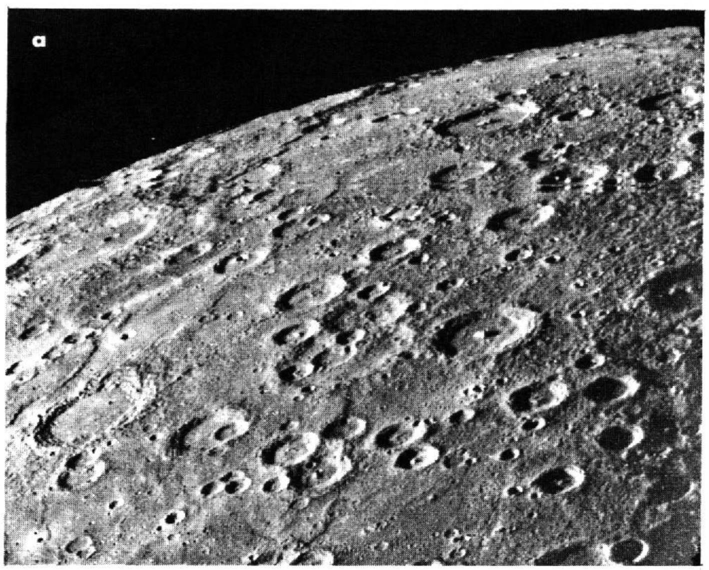
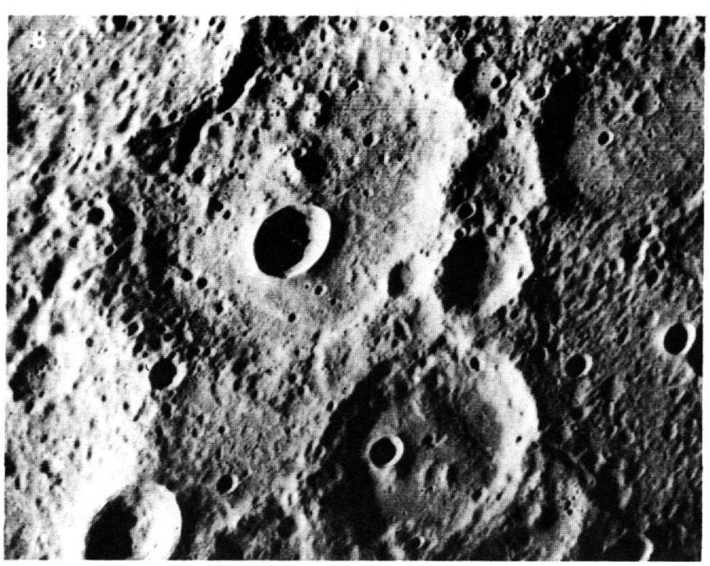
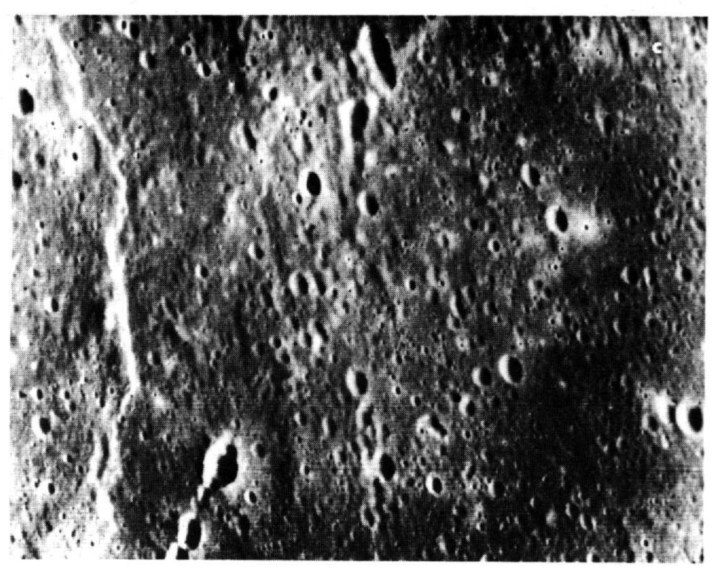


Fig. 3. (a) View of Mercury's northern limb taken from 77,800 km. A prominent east-facing scarp (also seen near the northern limb in Fig. 1 a) extends from the limb southward for hundreds of kilometers. The "tear" in the limb was caused by a loss of data. The area shown is about 580 km wide. (b) Close-up view taken from 19,370 km, revealing several old craters of intermediate size with a smaller sharp crater about 12 km in diameter. The rims of these older craters have been denuded by smaller craters. This picture was taken just before Mariner 10 entered the Sun's shadow (on the dark side). The area shown is 122 by 145 km. (c) High-resolution photograph taken from 7342 km shortiy after encounter, showing plains materials at 25°N latitude and 161°W longitude. Both primary and secondary impact craters can be recognized, the secondary craters being less circular and often forming clusters and chains. The largest craters are about 2 km across.





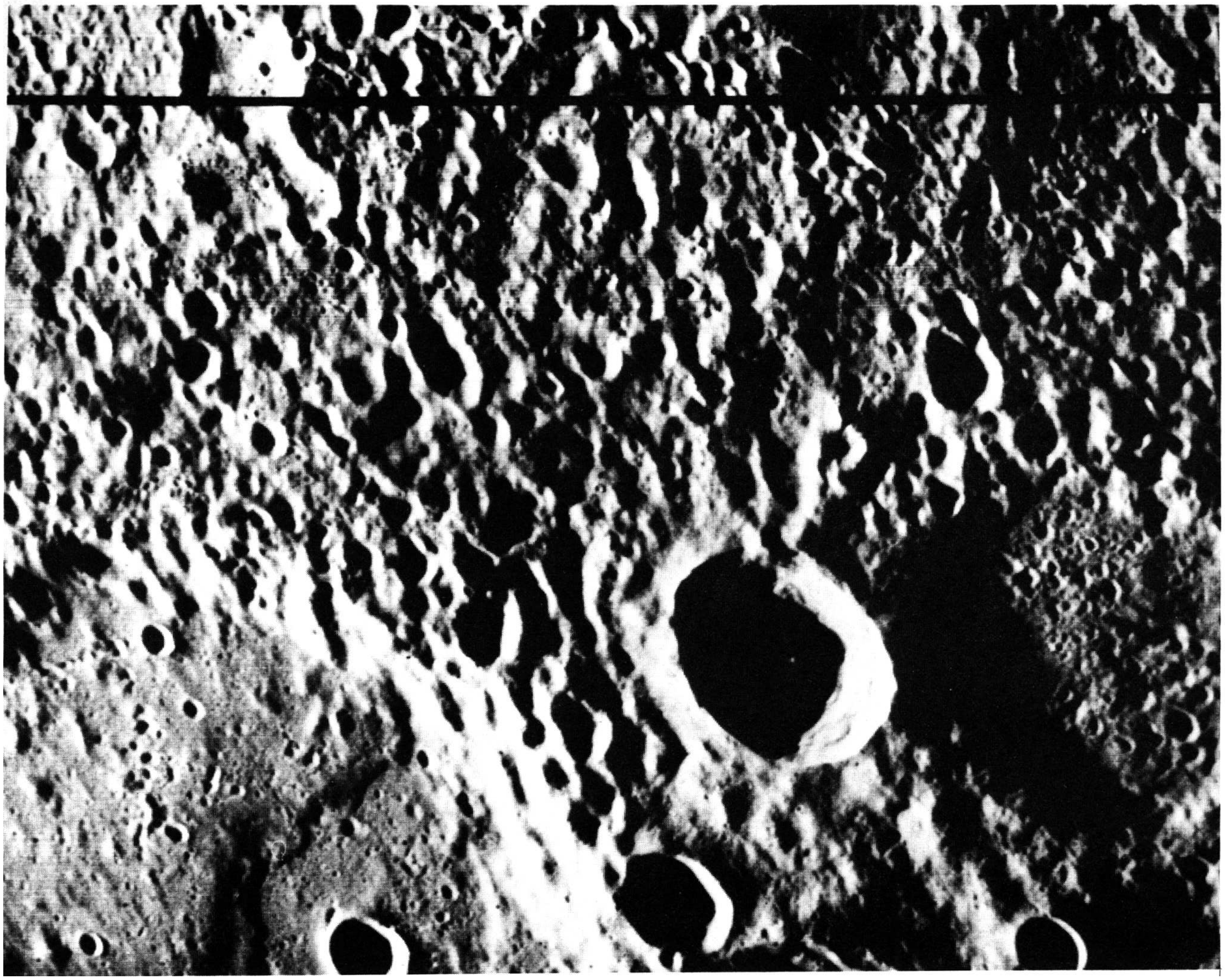


Fig. 4. The long shadows in this picture taken near the terminator help to bring out the roughness of this heavily cratered terrain. The large sharp crater to the right and below the center of the frame is about 25 km across. Part of a 100-km, flat-floored crater can be seen in the lower left corner. The flat floor apparently results from subsequent filling by plains material. The lobate scarp on the floor suggests a volcanic origin for this material. The smoothness and lack of continuous cratering is indicative of younger age than the surrounding terrain, which is peppered by craters, many of which may be of secondary impact origin.

2) The heavily cratered surfaces on Mercury record the final periods of heavy impact bombardment at Mercury. We consider it likely that those landscapes include at least some topographic features which have survived from the end of tangible accretion. Since planetwide melting would have destroyed such topographic features, Mercury's major chemical differentiation must have taken place before the end of accretion there. Similarly, there can have been no tangible atmosphere, primitive or secondary, about Mercury since those topographic features formed, because eolian processes would have modified them, as on Mars. An early speculation by Kuiper that Mercury's high density might reflect an extraordinary erosion of surface material by anomalous solar activity likewise is not confirmed.

3) In the half of the planet observed by Mariner 10, Mercury, like the Moon, seems to exhibit a hemispherically nonuniform distribution of flooded basins. If this impression is valid, previous explanations of the near-side/far-side dichotomy of the Moon which involve processes peculiar to the presence of the Earth may require reevaluation.

4) Mare-like surfaces now have been formed on the Moon, Mars, and Mercury which show a surprising similarity in accumulated impacts, although only those of the Moon have been dated radiometrically. The impacting objects traditionally have been regarded as asteroids or comets. A strong decrease in flux between Mars and Mercury had generally been expected. Yet, barring extraordinary coincidence in both age and local fluxes, no strong dependence on heliocentric distance in postaccretion

impact flux is suggested by the Mariner 10 pictures. The Mercury results may lend support to the recent speculation of Soderblom *et al.* that the impact flux histories of Mars and the Moon (and, by inference, Mercury) have been rather similar.

These preliminary conclusions carry important suggestions concerning the origin and evolution of the terrestrial planets. Widespread cratering and basin formation dating back to the final stages of accretion may be common to their early history. Major chemical differentiation well before the end of accretion is suggested for Mercury; perhaps this is a significant clue to the origin of other objects in the inner solar system. The Mariner 10 flyby of Mercury ultimately may contribute significantly to the understanding of the early history of our own planet.

The return of close-up television pictures from Mercury is a remarkable accomplishment reflecting the skills and perseverance of many at JPL, Caltech, Boeing, and NASA Headquarters. In the initial scientific interpretation we have benefitted from the aid of our Television Team Associates, Dr. Audoin Dollfus of l'Observatoire de Paris, Mr. James Anderson of Caltech, and especially Dr. John Guest of the University of London Observatory. Professors Robert P. Sharp and Arden L. Albee of Caltech provided valuable criticisms.

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MARINER 10 TV POINTING ANGLES

Mariner 10 began taking TV pictures of Mercury on 23 March 1974 (near 240 degrees on Fig. 5), a week after the third Trajectory Correction Maneuver (TCM-3), from a distance of 3,300,000 miles. Photography was intermittent for the next 4 days, but became almost a continuous operation on 28 March, taking one picture every 42 seconds. However, Mariner 10 was unable to photograph Mercury during the half-hour around the time of its closest approach (0^m on Fig. 6) on 29 March because the flight path had been targeted to pass behind the planet on the night side. A further constraint was a mechanical stop on the Science scan platform, which prevented the TV cameras from pointing any closer than 58 degrees from the Sun line. While Mariner 10 was still in Earth's shadow (occultation), the cameras started taking TV frames of Mercury's far side from the closest possible altitude of about 3600 miles. Since the planet blocked radio communications at that time, the frames had to be tape-recorded for later transmission to Earth. Some of these pictures are shown in this Status Bulletin. Periodic photographic operations continued for another 5 days until 3 April when the spacecraft was 2,200,000 miles past Mercury. More than 2000 TV frames were transmitted to the DSN 64-meter tracking stations around the World, in California, Canberra, and Madrid.

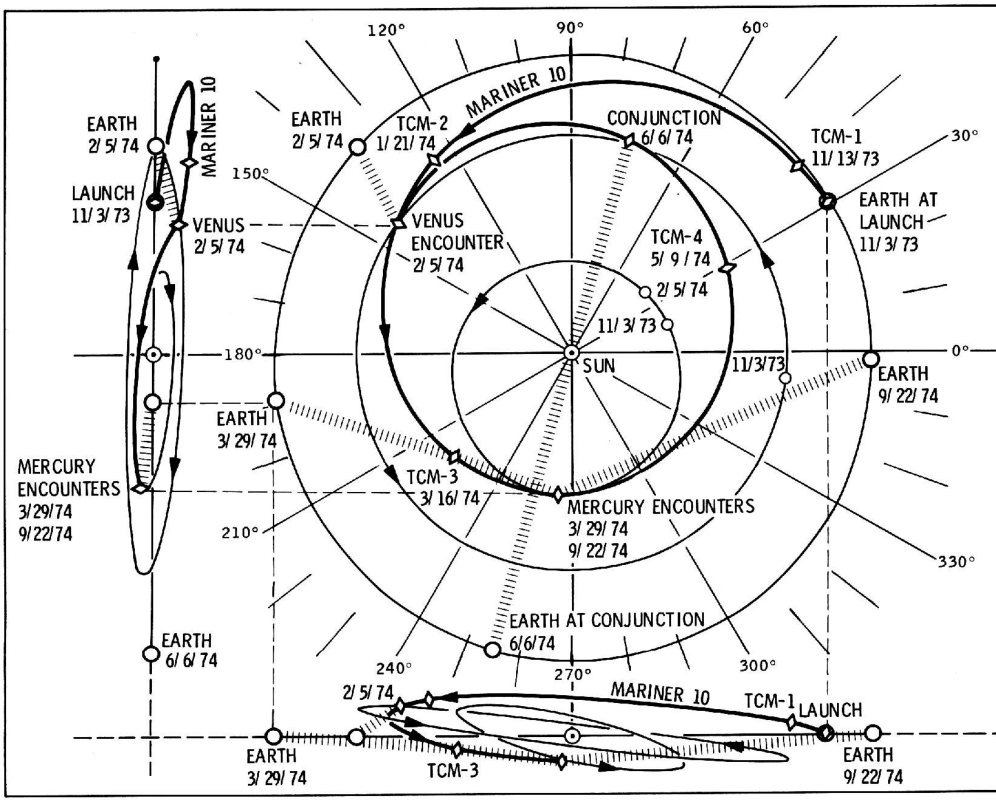

Fig. 5. Mariner 10 Trajectory Viewed from Above and Edge-On; Relative Inclinations are 3 deg for Venus and 7 deg for Mercury

Mariner 10 is now well along into its Extended Mission. The fourth Trajectory Correction Maneuver (TCM-4 on Fig. 5) is scheduled for 9-10 May, which should permit a second encounter with Mercury on 22 September. Results of this maneuver will be published in the next Status Bulletin. Since the information desired about the planet's atmosphere was obtained during the first encounter (29 March), this second flyby will be targeted so as to permit photography of the sunlit side from 46,000 km altitude. Earth, nearly 6 months later (176 days), will be on the opposite side of its solar orbit. Meanwhile, Mercury will have completed two circuits around the Sun.

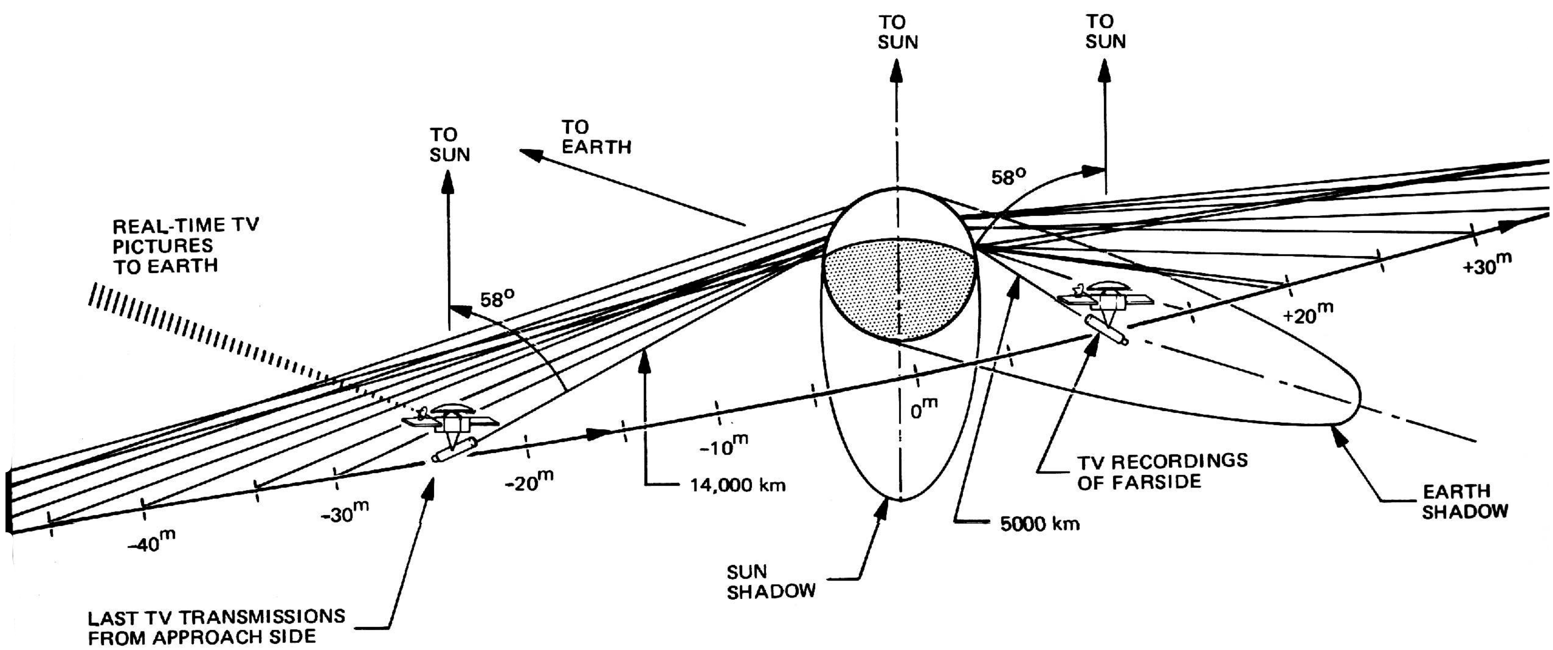

Fig. 6. Mariner 10 Mercury Encounter Flight Path and TV Camera Sighting Lines During the Hour Before and After Closest Approach