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Preliminary geomorphological observations of the photographs of Mercury transmitted by Mariner 10

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Planetologia. – *Preliminary geomorphological observations of the photographs of Mercury transmitted by* Mariner 10. Nota (*) del Socio Piero Leonardi.

Riassunto. — Vengono esaminate dal punto di vista geomorfologico le prime fotografie astronautiche del pianeta Mercurio. Da esse risulta che la superficie del pianeta presenta notevoli analogie con quella della Luna, particolarmente con quella della faccia nascosta del satellite. Sono numerosissime le strutture crateriche di ogni tipo, con e senza picco centrale, comprese quelle con raggera brillante, che evidentemente sono le più recenti. Molti crateri si possono ritenere di origine meteoritica, ma anche su Mercurio vi sono evidenti indizi di attività vulcanica. Alcune fotografie mostrano chiare testimonianze di rilevanti fenomeni tettonici.

The regrettable cessation of the astronautical studies of our satellite by NASA came just when, due to their excellent success, we began to know something precise and specific about the geological characteristics of the Moon. This cessation was in some part compensated by the arrival of the first splendid photographs of the surface of Mercury taken by *Mariner 10* USA. Their arrival coincided exactly with a planetological symposium organized last April by the Lincei Academy.

They were accompanied by equally splendid photographs of Venus and Jupiter. These photographs, although very interesting from a general planetological point of view, are not particularly so from a geological point of view because the soil of Venus and—if it exists—of Jupiter, is completely covered by thick gases.

Because Mercury has a highly rarefied atmosphere, its surface is very clearly visible with all its morphological particulars in the photographs of *Mariner 10*. The photographs are of excellent quality revealing striking geological analogies with the Moon's surface, especially when compared to the lunar farside.

I wish to give hearty thanks particularly to my colleagues J. F. McCauley, F. J. Colella, S. Miyamoto, G. M. Katterfeld and Y. Khodak, and my friends Dr. M. Pinti and G. Ruggieri for giving me precious photographic material, valuable bibliographical indications and personal communications which were of great help to me in this study.

Some planetologists did not wait for the astronautical photographs of Mercury and attempted to draw their conclusions on the geological characteristics, and even on the tectonic structure of the planet, based on telescopic observations which are, as is known, extremely difficult to obtain.

(*) Presentata nella seduta del 29 giugno 1974.

These studies were based on the characteristics and the distribution of zones of diverse *albedo*, which are, however, rather poorly defined and do not always correspond to each other in the drawings of various astronomers. These zones, visible on the surface of Mercury, are drawn in some hermographic planispheres, particularly those prepared by G. Schiaparelli (1889), G. Fournier and I. Sormano (1926), E.M. Antoniadi (1934), D. Cruikshank and G. Chapman (1967), and H. Camichel and A. Dollfuss (1968).

In these planispheres, dark zones are distinguishable, as on the Moon, which astronomers call "*maria*" or "*solitudines*" (for ex. *Mare* or *Solitudo Baal*, *Mare Jovis*, *Mare Argyphontae*, *Mare Phoebi*, *Mare Aphrodites*, *Mare Criophori*, *Oceanus Hermae Trismegisti*, etc.) or "*fretus*" (for ex. *Fretus Neptuni*, *Fretus Alarum*, etc.) and light zones corresponding to the Moon's "*terrae*" (for ex. *Heliocaminus*, *Apollonia*, *Pentàs*, *Pieria*, *Phaetontias*, etc.) (1).

Also in Mercury's case, however, the " seas " have nothing in common with those of the Earth since Mercury does not have a hydrosphere.

The geological investigations I mentioned above have given birth to a new branch of planetology—hermology—and have recently been summarized by my friend and colleague Y. Khodak (1972 a, 1972 b) who, in his recent manual on planetology (1972 b), gives a specific description of not only the geomorphological characteristics of Mercury, but of the geotectonic structure of the planet and its tectogenesis (*op. cit.*, p. 29–35). His interpretations are based upon his own observations as well as material obtained through telescopic studies by other Authors, especially by Cruikshank and Chapman (1967) and by Camichel and Dollfuss (1968).

Khodak accompanies his treatment of the argument with a description of the succession of events that formed the actual structure of the planet and a series of structural maps, from which I have taken one of the most general in character, reproduced as figures 1-2.

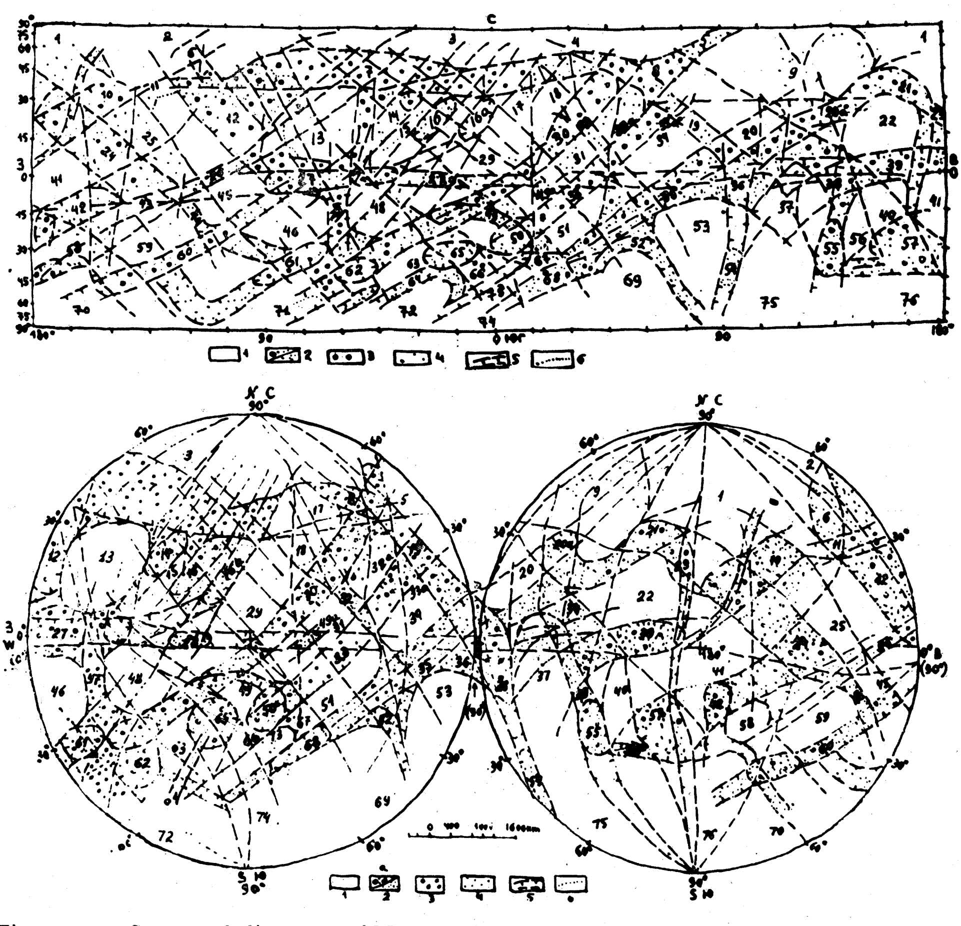
In his other work (1972 a), Khodak presented an analogous description in which the hermesian succession is confronted with that of the Moon and Mars.

It will be interesting to see how many of these hypotheses will be confirmed when sufficient documentation from *Mariner 10* and from other future astronautic undertakings becomes available.

That which especially struck the planetologists examining the photographs taken by *Mariner 10*, was, as we said, the close analogy—even closer than that already verified in the case of Mars—of the morphological characteristics of the surface of Mercury with that of the Moon, especially with regard to the extraordinary abundance of " crater-like " structures of every type and dimension.

(1) Hermographic nomenclature is still substantially that of E.M. Antoniadi, with modifications and additions by G. Katterfeld (1970) and others.

This confirmed what astronomers have believed for some time. In fact K. Beneš and G. N. Katterfeld affirmed that " *by analogy with the Moon it may be assumed that the dark areas of Mercury (maria, solitudines) are flat lowlands, while the terrae (uplands) display the pattern of abundant ring structures of different types and sizes* " (1967, p. 80).



Figs. 1–2. – Structural diagrams of Mercury (after the cartographic data of Cruikshank and Chapman, 1967, Nesterovic, 1968 and others) in isocylindrical projection (fig. 1) and hemispherical representation (fig. 2).

Numbers: Names of the various structures: 1) oldest massif remains; 2) depressions: Mare, Fretum, Sinus, Lacus; *a*) sunken areas with lowest albedo; 3) depressions with darkest albedo values (after Schiaparelli, 1886–1889, Antoniadi, 1934 and others); 4) development fields with grey albedo; 5) principal deep fracture zones and others, linear and arched zones, direction of the sunken blocks; 6) structures of uncertain position.

(by Yu. A. Khodak, 1972 b).

V. de Callatay and A. Dollfuss also point out that the photometric analysis of Mercury " *revèle une surface très chaotique, constituée par un matériau criblé de cavités jointives irregulières et de toutes dimensions* " (1968, p. 52) and that " *la courbe polarimétrique de Mercure présente une similitude presque parfaite avec celle de la Lune, ce qui prouve que les sols des deux astres ont des* *structures quasi identiques*" (*Op. cit.*, p. 52, 53). "*On peut ainsi conclure que le sol de Mercure, comme celui de la Lune, est criblé de nombreuses cavités et qu'il est recouvert d'un dépôt de poudre extrêmement fine, d'une infime densité*", (*Op. cit.*, p. 53).

The same Authors said that "*il est infiniment probable que des cratères analogues à ceux de la Lune doivent y exister. Logiquement ils devraient même être plus vastes puisque la vitesse de Mercure est 1,6 fois supérieure à celle de la Terre et que les chocs dus aux impacts y développent par conséquent, pour une même masse, une quantité d'énergie un peu plus grande*" (*Ibidem*).

And, more recently, G. N. Katterfeld again expressed the conviction "*that mare areas of Mercury as on Moon are the effusions of dark-colored basaltic lavas. Bright areas - terrae - of this planet like the Moon and Mars must be covered with abundant craters and cirques*" (1970, p. 144).

Undoubtably the visible structures on the surface of Mercury represented in the photographs that I have of *Mariner 10* are analogous, even in details, to those of the Moon. However in the photographs at my disposal for this study, it can be noted that vast "marine" depressions, such as those on the Moon, which are smooth and relatively devoid of large craters, seem quite rare both in the photographs reproducing vast expanses of Mercury's surface (Plates I, VIII) and in those, with two exceptions (Plate V, fig. 2; Plate VII), showing the surface in detail (Plates II–VII). One might have expected the existence of such depressions based upon the telescopic observations which revealed dark areas on the surface of Mercury. On the other hand, their absence is not very surprising. In fact not even on Mars is there evidence of a relevant morfological analogy between the dark areas on the telescopic planisphere of this planet and "marine" depressions, comparable to those of the Moon. This deduction results from the observation of some aerographic maps based on the *Mariner* photographs.

In every case these observations refer to the example of the surface of Mercury reproduced in Plate I. It cannot, however, be excluded that "marine" surfaces comparable to those of the Moon exist in the remaining part of the planet as the photographs reproduced in fig. 2 of Plate V and in Plate VII would seem to indicate.

From an examination of the photographs taken at closer range, one has the impression that the surface of Mercury is even rougher than that of the Moon and certainly more rugged than that of vast areas of Mars which are almost devoid of craters.

Regarding Mercury, however, it is better to wait for further knowledge on the subject because this greater ruggedness could also be in part due to particular conditions of illumination. In fact, the lunar photograph of Ranger IX, which I reproduced in an earlier work (1972, p. 145), was taken in a very weak light and shows notable similarities, from this point of view, to the close range photographs of Mercury.

In any case, even taking this into account, I still maintain that the surface of Mercury seems even more rugged than that of the Moon.

The crateric structures, as I already pointed out, are numerous on Mercury and have the same characteristics of those of the Moon. There are cirques and craters more or less of all types singled out on the Moon (P. Leonardi, 1972, pp. 153-159), with or without central peaks and made up of craters surrounded by bright halos (see Plates I and VII) that indicate recent formation.

Indications of important tectonic phenomena are very evident on Mercury, particularly along fractures, that often intersect the crateric structure (Plate III, fig. 2; Plate IV) and upheaving their valleys (Plate IV) until they assume, in some cases, the characteristics of "*en échelon*" craters. (Plate IV, A, B).

The following is a geomorphological description and interpretation of the most significant photographs taken by *Mariner 10* that I presently have at my disposal.

The surface of the planet is uniformly scattered with craters and cirques of various dimensions and presents notable morphological analogies to the lunar surface particularly to the bright highlands of the farside.

Among the craters almost all lunar types are present, from cirques of notable dimensions (the greatest has a diameter of about 200 Km) with smooth floors and no central peak, to craters of various types and dimensions, many of which have central peaks and some that have characteristic bright rays similar to the rays around fresh craters on the Moon. Of the latter, the bright spot visible almost in the center of the illuminated face is particularly notable. This spot corresponds to a group among which the crater Kuiper is located (cfr. Plate III, fig. 1).

Here and there, interesting crater alignments, seemingly explainable by a volcanic origin, may be observed.

The photograph reproduced in Plate II corresponds to a small part of the illuminated area reproduced in the photomosaic in the preceding Plate, and is situated approximately at the center of it.

Numerous cirques and craters, some having a typical central peak, are discernible. Particularly interesting are the small crater with the convex floor, comparable to the lunar *Marsenius*, that is found near the upper right hand corner (A) and the double crater, visible almost at the center of the photograph (B), which is evidently among the most recent with its characteristic halo of bright rays.

Fig. 1 of Plate III is a reproduction of a close-up of one of the most interesting crater groups on Mercury, which has a very evident bright halo and is visible almost in the center of the photo-mosaic of Plate I. This crater was named *Kuiper* in honor of the recently deceased planetologist.

The large crater (A) in the center of the photograph has a diameter of 80 Km and has a central peak on which there appears to be an eruptive orifice. A minor, bright floored younger crater (B), 41 Km in diameter, has a central peak exactly on the perimeter of the crest of the wall of the larger crater and thus has all the characteristics of a parasite crater.

On the right side one can observe the alignment of craters of a constantly diminishing size (C–G). This entire complex is made up of craters that are not explainable by a meteoritic origin.

In the photograph reproduced in Plate III, fig. 2, the surface of Mercury is extremely rugged due to an enormous quantity of small craters that probably have a meteoritic origin and are in various stages of degradation although most are fairly fresh. Reliefs (A) and depressions (B) are discernible that are apparently independent of craters and are probably of tectonic origin. In the bottom lefthand corner, there is a portion of a 61 Km crater (C) that shows a flow front (D) extending across the crater floor and filling more than half of the craters. The smaller fresh crater in the center (E) is about 23 Km in diameter. From the shadows the summit of the central peak projects. Just to the right of this crater another larger crater is visible which is in a stage of advanced degradation (F) and its floor is torn up by many tiny impact or " secondary " craters.

The photograph of Plate IV is one of the most important taken by *Mariner 10*. The surface of the planet seems exceedingly rugged because of innumerable tiny meteoritic craters and a great quantity of low hills spread about without order.

The crater-form structures fall into various groups and are in diverse stages of conservation. The cirque with a flat floor, near the center of the photograph, is about 80 Km in diameter, and on its margins (A, B) partially presents the characteristics of " *en échelon* " craters (cfr. P. Leonardi, 1972, pp. 158, 181; fig. 6–69). The origin of the promontory near the edge of the cirque that can be seen at the bottom of the photograph (C) and that gives a bilobate appearance is not clear. The presence of a crater on the promontory itself could mean that it is linked with a " parasite " crater. Just to the right of this promontory, the cirque is clearly crossed by a fracture that continues N to S beyond the wall and presents alignments of coalescent craterlets (D, E) that are evidently of an eruptive origin, a phenomenon similar to lunar and terrestrial types (P. Leonardi, 1972, p. 295, fig. 14–56; p. 296, fig. 14–57; p. 297, 14–58 bis). Two elongated coalescent craters (F) are visible to the NW of the cirque. The series of very tiny and fresh craters that surrounds a small crater (G) in the SE area of the cirque is most interesting. The question is: are they " secondary " craters? On the floor of the same cirque there is a slight indication of a wrinkle ridge (H) that in part coincides with the course of the above-mentioned fracture.

In the upper left-hand corner a part of another larger cirque is visible (I). It also has a flat, smooth floor and has walls that are only slightly raised above the surrounding territory. The floor is particularly rugged as a result of numerous fractures and meteorite impacts, a condition which may also be observed in a third and smaller cirque visible at the lower edge.

The crater situated in the upper right-hand corner is similar in structure to lunar craters whose inner slope presents concentric block sinking (type F, P. Leonardi 1972, p. 158). It is not clear, however, if it has a multiple central peak or presents random structures of another type that make the surface of its floor appear extremely rugged. In general, the rest of the craters in this zone do not have evident central peaks.

In the center of the photograph a rille (L), that is completely analogous to lunar types, is clearly distinguishable. As in the case of the greater part of these rilles, it probably corresponds to a lava channel or a collapsed lava tube (P. Leonardi, 1974).

The large valley (M) that can be seen at the right of the same photograph is most interesting. It is 7 Km wide and more than 100 Km long. It has many analogies to the lunar *Vallis Alpina* and another lunar valley located to the west of *Landsberg* crater (P. Leonardi, 1972, p. 140, fig. 5–54). As its analogous lunar structures, it probably corresponds to a tectonic trench.

In the photographs in Plate V, fig. 1, one can see the striking ruggedness of the planet's surface that is pitted by innumerable small craters of meteoritic origin or " secondary " craters. The diverse state of conservation of the major craters is made particularly clear by a comparison of the small, fresh crater with a bicuspid peak (A) that is situated almost in the center of a larger, extremely degraded crater (B). The newer crater (almost centered in the photo) is about 12 Km. across. It should be pointed out that the alignment of craters in the right half of the photograph (C, D, E) is an alignment that does not indicate meteoritic origin.

The photograph in Plate V, fig. 2, is one of the highest resolutive pictures obtained during the mission of the *Mariner 10*, so highly so that craters as small as 150 m across can be seen.

The region visible in the photograph is notably smoother than in the photographs illustrated below (Plates III, IV) and thus corresponds to the surface of the lunar " seas ".

The idea is also reinforced by the presence, on the right side of the photograph, of one of those wrinkle ridges (A) that are usually seen on the surface of the lunar " seas ".

The greater part of the many small craters that are scattered on the surface, in various stages of degradation, are probably due to the impact of meteorites.

There is, however, an elongated cavity (B) and a series of more or less coalescent craters (C , D) that are analogous to lunar structures (cfr. P. Leonardi, 1972, p. 295, fig. 14–56). These features are extremely difficult to explain in terms of a meteoritic origin, whereas they correspond perfectly to certain terrestrial structures which are of stablished volcanic origin (cfr. P. Leonardi, 1972, p. 296, fig. 14–57; p. 297, fig. 14–58 bis).

Finally, one should note the bright spot that surrounds a small crater (E), clearly recently formed, on the left side of the photograph.

In the photograph reproduced in Plate VI, the surface of Mercury again shows its extreme ruggedness. Numerous small craters are apparent; many of them are of meteoritic origin, but others, especially those in the vicinity of the large crater at the right, are probably " secondary " craters. The latter crater is the type characterized by stepping on the internal slopes (type F, Leonardi, 1972, p. 158). A very complex group of central peaks is visible on the floor of this crater. Here and there, one notes small coalescent craters and clear indications of fracture lines.

CONCLUSIONS

The photographs of Mercury sent by *Mariner 10* USA demonstrate striking morphological analogies between the surface of Mercury and the Moon, particularly with that of the Moon's farside. Although the photo-mosaic of Plate I and the greater part of the close-ups do not show extensive " marine " depressions similar to those of the Moon, it cannot be excluded that such areas do exist in zones not examined in this study.

The crater structures of Mercury, with or without central peaks, are almost entirely made up of types found on the Moon, including those with bright halos. These obtain notable dimensions—up to 200 Km in diameter—but in the photographs that are available one cannot discern large basins and " crater seas " comparable to those of the Moon.

Relative to their nature and origin, the same considerations are valid for Mercury as were proposed for the Moon. Some craters seem to be of meteoritic origin, but there are also structures that have the morphological characteristics (double ring craters, parasite craters, etc.) and the alignment that seem to indicate a volcanic origin. In the last category, one can include the incidence of characteristic rilles.

There is also evidence of considerable tectonic dislocations, mainly due to fractures which also determine the " *en échelon* " structure of some craters.

APPENDIX

While this paper was being printed, the NASA Jet Propulsion Laboratory kindly sent me a photograph and a photomosaic which are very interesting because of the new elements that they add to our geomorphological knowledge of Mercury.

In fact, this new photographic material indicates that there are vast, dark, smooth expanses with relatively few craters on Mercury. These areas would seem to correspond to the lunar " seas " (Plates VII and VIII).

The photograph in Plate VIII further shows that, on Mercury just as on the Moon, there are circular " basins " of huge size such as the one which is visible at the day-night terminator at left center, having a diameter of about 1,300 Km.

In the same photograph (Plate VIII), the bright rayed craters are particularly well developed; one of them has a bright halo of considerable dimensions. One may also note a curvilinear feature running from east to west and then to the north, that resembles the bright rays but does not belong to a radial cluster.

References

ANTONIADI E. M. (1934) – *La planète Mercure*. Paris.

BENEŠ K. and KATTERFELD G. N. (1967) – *On the comparative geology of planets and the term Planetology*, « Problems of Planetology », *1*, Ostrava.

BÜLOW K. V. and REICHSTEIN M. (1969) – *Astrogeologic und ihre prognose*, « Ber. deutsch. Ges. Geol. Wiss. A. Geol. Paläontol. », *14* (1), Berlin.

CAMICHEL H. and DOLLFUSS A. (1968) – *La rotation et la cartographie de la planète Mercure*, « Icarus », *8* (2).

CRUIKSHANK D. P. and CHAPMAN C. R. (1967) – *Mercury's Rotation and Visual Observations* (*New Map of the surface of the Planet Mercury*), « Sky and Telescope », *34* (1).

DE CALLATAY V. and DOLLFUSS A. (1968) – *Atlas des Planètes*. Albert de Visscher, Bruxelles. Gauthier-Villars, Paris.

KATTERFELD G. N. (1970) – *Topography and nomenclature of Mercury*, « Vestnik of Leningrad University », *12*, « Geology and Geography », *6*, Leningrad. (In lingua russa).

KHODAK J. A. (1969) – *Hermesologic-Geologic des Merkurs*. In: Nachrichten der Akademie der Wissenschaften der USSR « Serie Geologie », *10*.

KHODAK J. A. (1972 a) – *Merkur*, « Ideen d. exakten Wissens. Wiss.u.Tekn. i. d. Sowjetunion », *1*.

LEONARDI P. (1972) – *Vulcani e bolidi sulla Luna e su Marte*. Manfrini, Calliano.

LEONARDI P. (1974) – *On the origin of the lunar sinous and meandering rilles*. « Mem. geopal. Univ. Ferrara », *3* (1).

MOORE P. (1970) – *Atlante dell'Universo*. Mondadori, Milano.

OBSERVATOIRE JARRY-DESLOGES-SÉTIF (1926) – *Observations des surfaces planetaires*. Fasc. VII, années 1919 et 1920, Abbeville.

ХОДАК Ю. А. (1972 b) - *География е Геология планет* (*планетология*). Москва

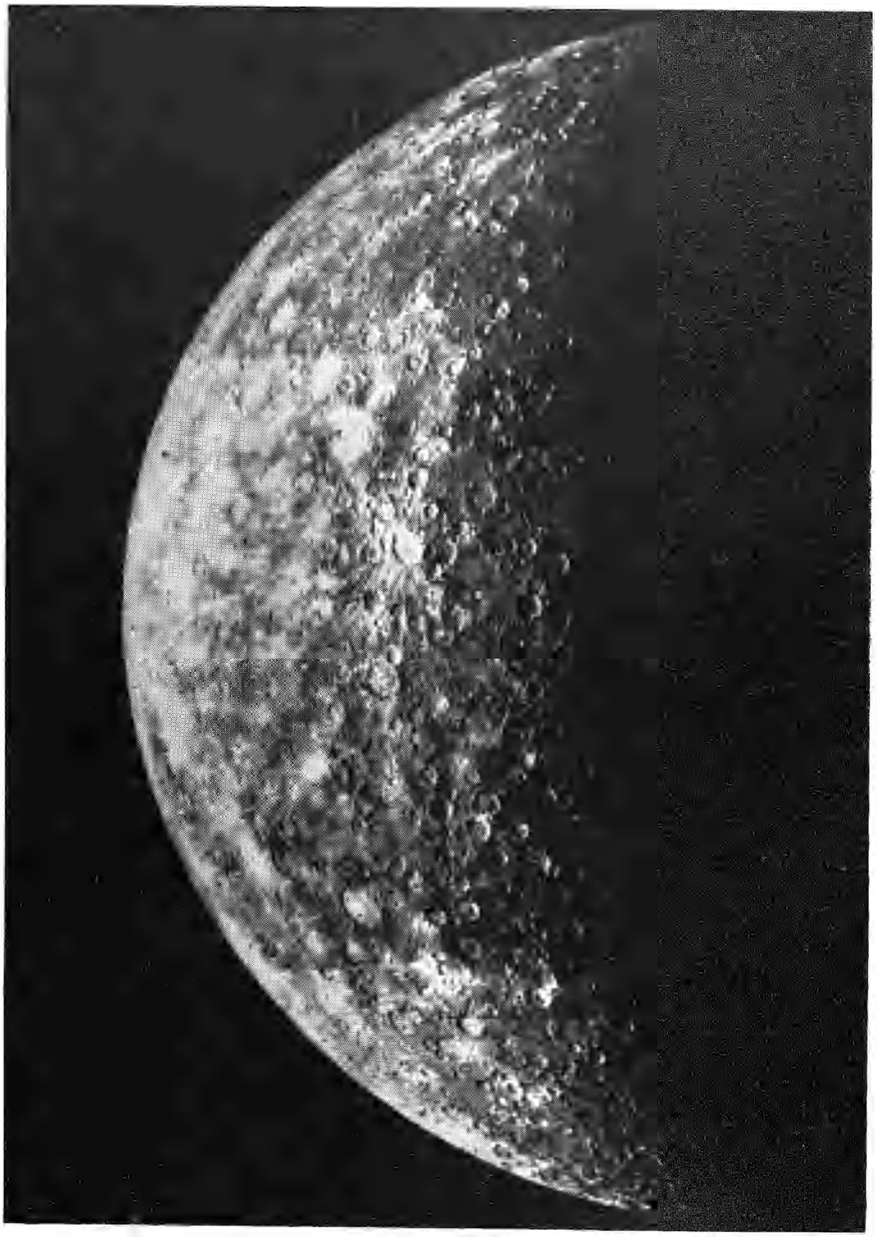
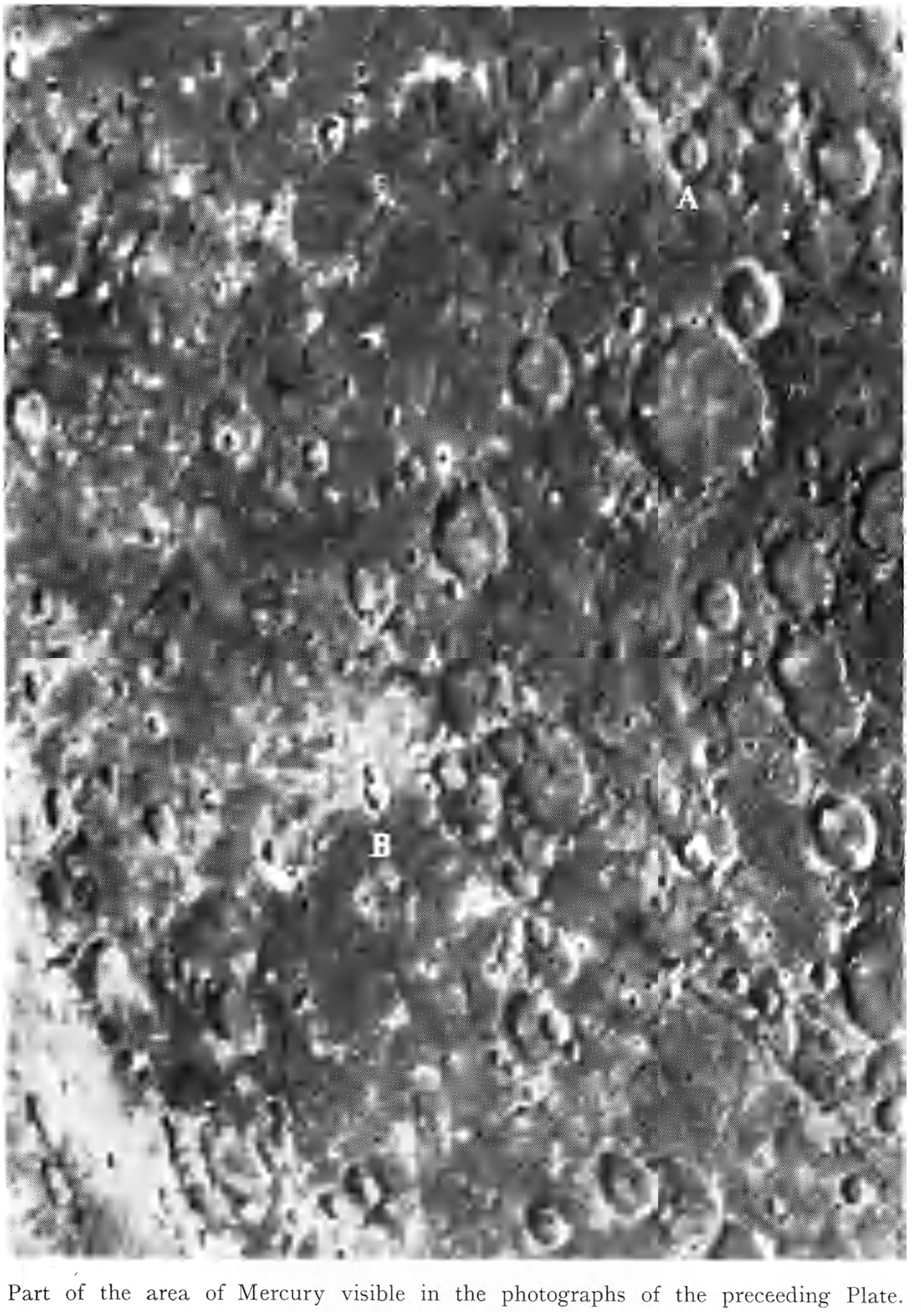


Photo-mosaic of Mercury composed of 80 photographs taken by *Mariner 10* USA, March 29, 1974, from a distance of 200,000 Km. About two-thirds of the portion of the planet is in the southern hemisphere. In the photo-mosaic, features as small as 11 Km can be distinguished. The geomorphological interpretation is on pages 207, 208.

(Original NASA photo, courtesy of USIS, Rome).



Part of the area of Mercury visible in the photographs of the preceeding Plate. The geomorphological interpretation is on page 208.

(Original NASA photo, courtesy of USIS, Rome).

Fig. 1. – The Kuiper crater of Mercury photographed March 29th, 1974 by *Mariner 10* USA from a distance of 88,450 Km. The geomorphological interpretation is on pages 208, 209.

(Original NASA photo, courtesy of USIS, Rome).

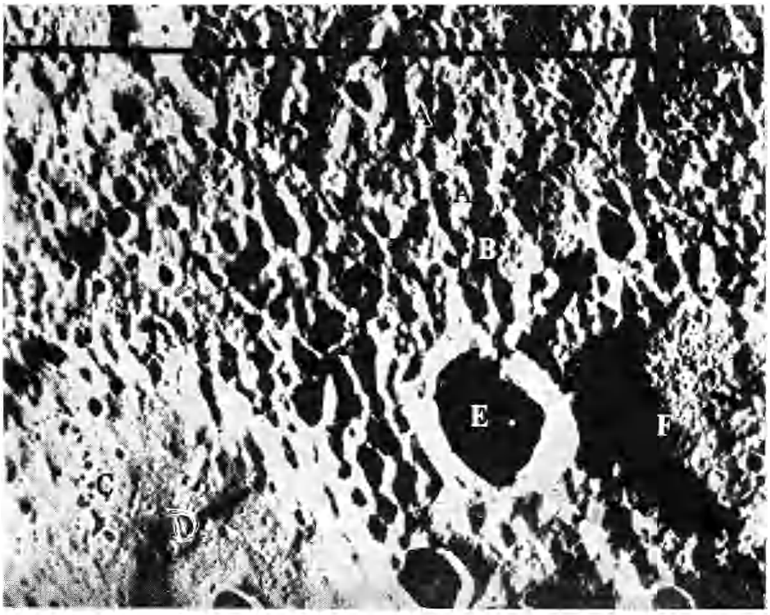
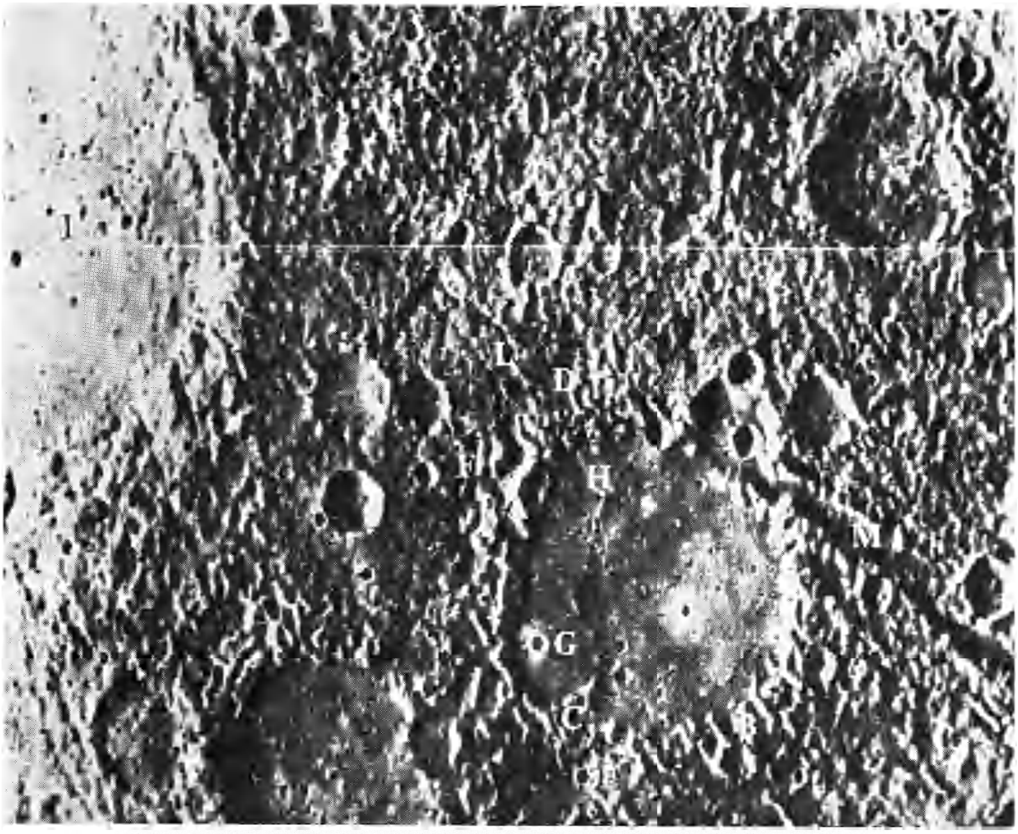


Fig. 2. – Photograph of Mercury taken by *Mariner 10* USA March 29th, 1974 when the spacecraft was 18,200 Km from the planet. Craters as small as 1 Km across are visible. The geomorphological interpretation is on page 209.

(Original NASA photo, courtesy of USIS, Rome).



Photograph of Mercury taken March 29th, 1974 by *Mariner 10* USA from a distance of 35 Km and covering an area of 290×220 Km. The geomorphological interpretation is on pages 208, 209, 210.

(Original NASA photo, courtesy of USIS, Rome).

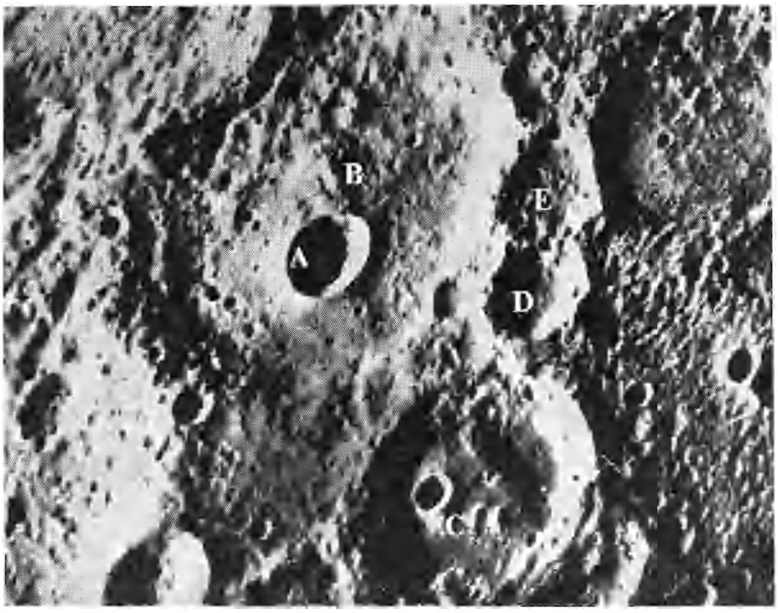


Fig. 1. – Photograph of Mercury taken March 29th, 1974 by *Mariner 10* USA from a distance of about 20,700 Km and covering an area of 130×170 Km. The geomorphological interpretation is on page 210.

(Original NASA photo, courtesy of USIS, Rome).

Fig. 2. – Photograph of Mercury taken by *Mariner 10* USA from a distance of about 5,900 Km, covering an area of 50×40 Km. The geomorphological interpretation is on page 210.

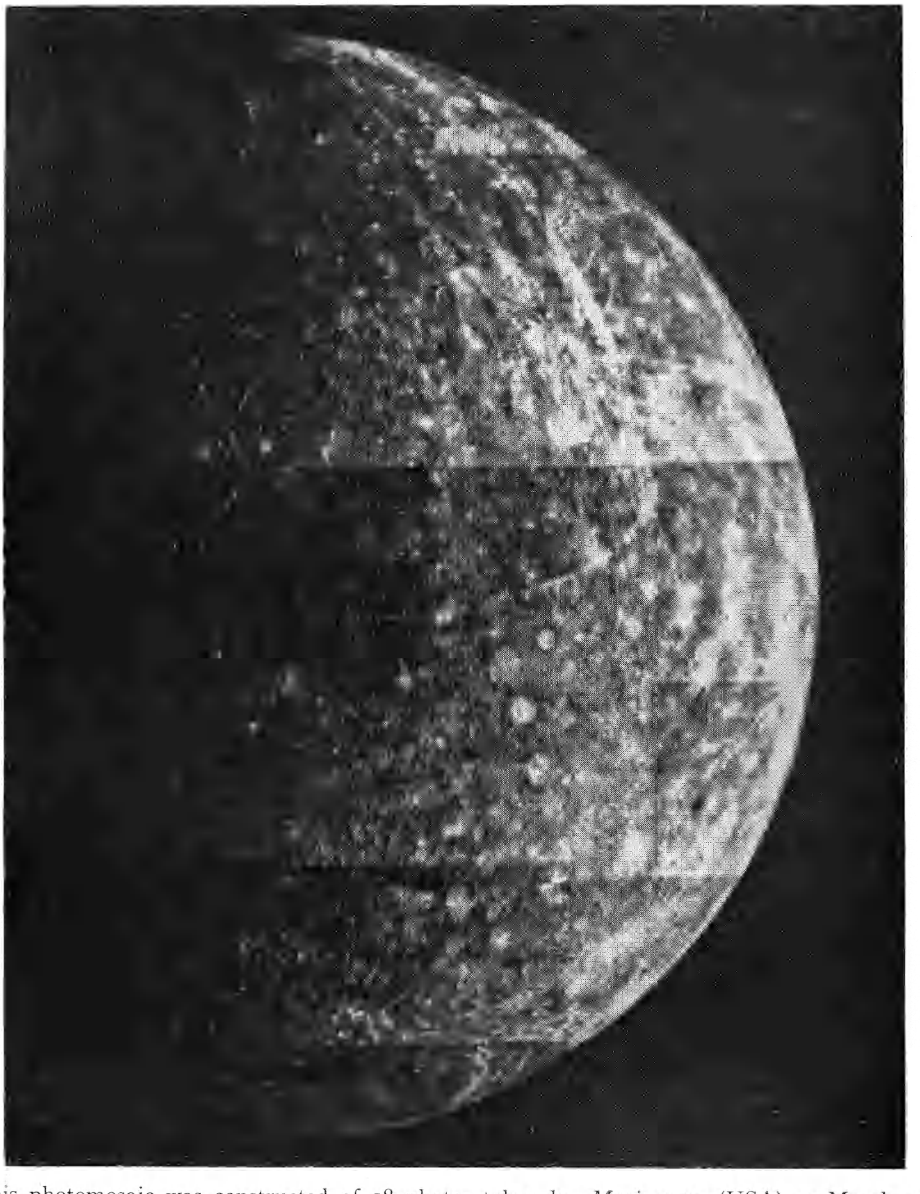
(Original NASA photo, courtesy of USIS, Rome).

Photograph taken by *Mariner 10* USA on March 29th, 1974 from a distance of 31,000 km. The large crater at the right has a diameter of about 100 km. Top is at the left. The geomorphological interpretation is on page 210.

(Original NASA photo, courtesy of USIS, Rome).

Photo taken by *Mariner 10* (USA) on March 29, 1974, from an altitude of 36,800 Km. A relatively uncratered area is visible which probably corresponds, at least in part, to mare materials such as those found in the lunar " seas ". The prominent sharn crater with a central peak at the center of the photo has a 30 Km diameter. The bright halo belongs to the smaller crater at the center, which has a diameter of 10 Km. Top is at the left.

(Original NASA photo, courtesy of Jet Propulsion Laboratory, Pasadena).



This photomosaic was constructed of 18 photos taken by *Mariner 10* (USA) on March 29, 1974, at a distance of 210,000 Km from the surface of Mercury. The north pole is at the top and the equator extends from left to right about two-thirds down from the top.

(Original NASA photo, courtesy of Jet Propulsion Laboratory, Pasadena).