DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MERCURY
1:5,000,000 GEOLOGIC SERIES
KUIPER QUADRANGLE
H 5M 0/36 G, 1981
I-1233 (H-6)

NOTES ON BASE

This map sheet is one of a series covering that part of the surface of Mercury that was illuminated during the Mariner 10 encounters (Davies and Batson, 1975). The source of map data was the Mariner 10 television experiment (Murray, 1975).

ADOPTED FIGURE

The map projections are based on a sphere with a radius of 2439 km.

PROJECTION

The Mercator projection is used for this sheet, with a scale of 1:5,000,000 at the equator. Latitudes are based on the assumption that the spin axis of Mercury is perpendicular to the plane of the orbit. Longitudes are positive westwards in accordance with the usage of the International Astronomical Union (IAU, 1971). Meridians are numbered so that the reference crater named Hun Kal (lat -0.6°) is centered on long 20° (Murray and others, 1974; Davies and Batson, 1975).

CONTROL

Planimetric control is provided by photogrammetric triangulation using Mariner 10 pictures (Davies and Batson, 1975). Discrepancies between images in the base mosaic and computed control point positions appear to be less than 2 km.

MAPPING TECHNIQUES

Mapping techniques are similar to those described by Batson (1973a, 1973b). A mosaic was made with pictures that had been digitally transformed to the Mercator projection. Shaded relief was copied from the mosaics and portrayed with uniform illumination with the sun to the west. Many Mariner 10 pictures besides those in the base mosaic were examined to improve the portrayal. The shading is not generalized, and may be interpreted with nearly photographic reliability (Inge, 1972; Inge and Bridges, 1976).

Shaded relief analysis and representation were made by Patricia M. Bridges.

NOMENCLATURE

All names on this sheet are approved by the International Astronomical Union (IAU, 1977).

H–6: Abbreviation for Mercury (Hermes) sheet number 6.

H 5M 0/36 G: Abbreviation for Mercury (Hermes) 1:5,000,000 series; center of sheet, lat 0°, long 36°; geologic map, G.

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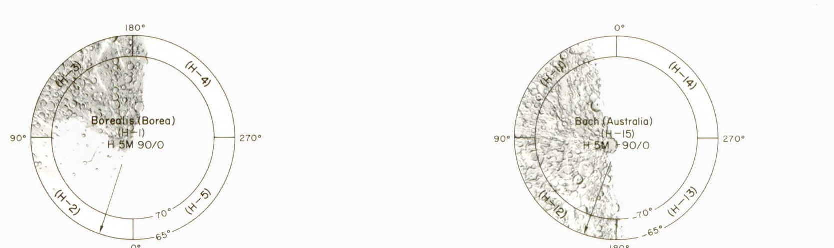
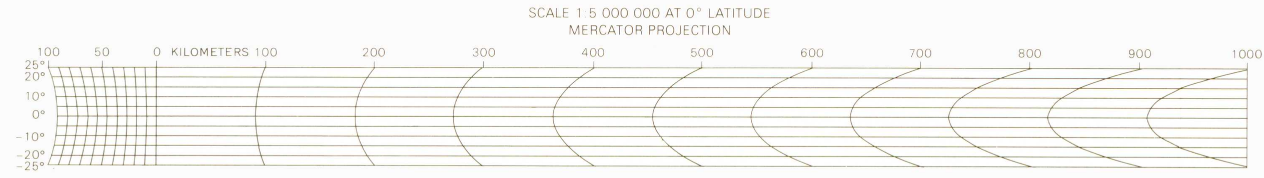
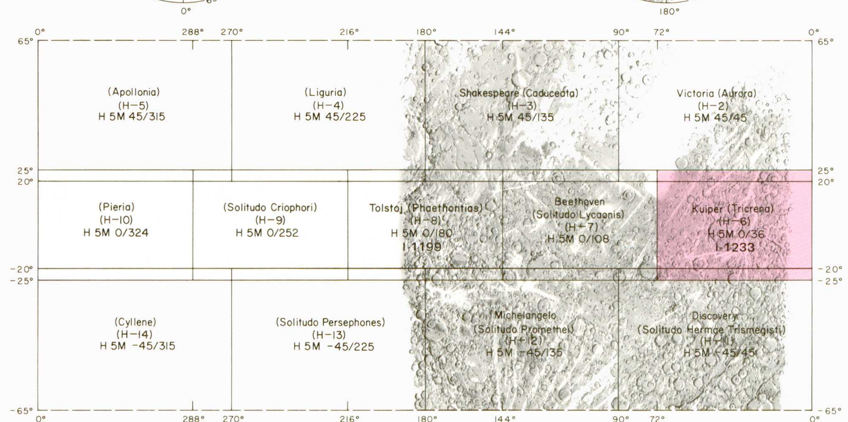




SCALE 1:5 000 000 AT 0° LATITUDE
MERCATOR PROJECTION



QUADRANGLE LOCATION
Number preceded by I refers to published geologic map

Interior—Geological Survey, Reston, Va.—1981—G79727

Prepared on behalf of the Planetary Geology Program, Planetary Division, Office of Space Science, National Aeronautics and Space Administration under contract W-13, 709 in cooperation with Northeast Louisiana University (NASA grant NSG–7357) and Kansas State University (NASA grant NSG–7478).

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INDEX TO MARINER 10 PICTURES

The mosaic used to control the positioning of features on this map was made with the Mariner 10 pictures outlined above. Useful coverage was not available for the mosaic in the cross-hatched area; although part of that area was filled in visually from pictures of marginal quality that could not be included in the mosaic.

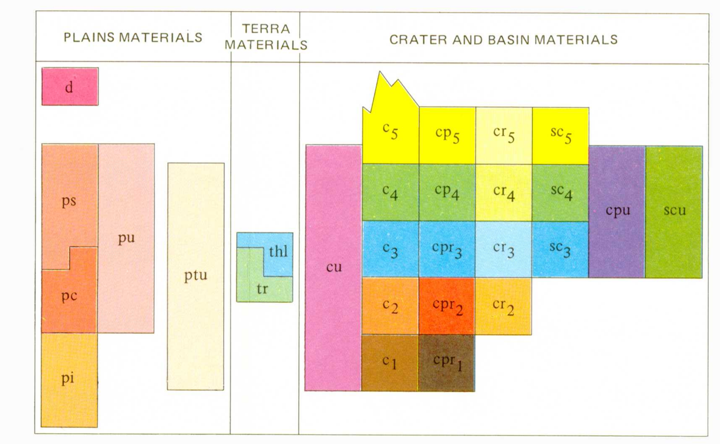
GEOLOGIC MAP OF THE KUIPER QUADRANGLE OF MERCURY

By

R. A. De Hon, D. H. Scott, and J. R. Underwood, Jr.

1981

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

PLAINS MATERIALS

d DARK MATERIAL—Albedo low: occurs as small patches in western part of quadrangle (8° S., 67°); some overlies bright rays of craters; locally fills crater floors. *Interpretation:* Basalt flows or pyroclastic material

ps SMOOTH PLAINS MATERIAL—Smooth, sparsely cratered surface occurs within craters and topographically low areas between craters. Albedo intermediate. Representative area: 1° S., 37°. *Interpretation:* Volcanic rock, clastic blanket generated by secondary impact events, or both

pc CRATERED PLAINS MATERIAL—Embays or fills most large older craters. Higher density of craters than smooth plains material; rough planar surfaces with lobate scarps and broad ridges. In many areas gradational with smooth plains material. Representative areas: 13° N., 37°; 6° N., 17°. *Interpretation:* Volcanic rock, clastic blanket generated by secondary impact events, or both. Rough surface results from buried and unburied primary and secondary craters. Crater density indicates age older than smooth plains

pu PLAINS MATERIAL, UNDIVIDED—Mapped in western part of quadrangle where high-sun illumination prevents reliable differentiation between smooth and cratered plains materials (units ps and pc) in craters and other depressions

pi INTERCRATER PLAINS MATERIAL—Hilly and highly cratered but intercrater areas are relatively smooth at scale of 5-10 km; most large craters subdued; many secondaries; embayed by and gradational with cratered plains (unit pc) in places. Representative area: 8° N., 47°. *Interpretation:* Oldest crustal material exposed in quadrangle, volcanic; probably includes ejecta from ancient craters and basins

ptu PLAINS AND TERRA MATERIAL, UNDIVIDED—Mapped only where resolution of topography is poor because of high-angle solar illumination. Bright rayed craters common. Albedo ranges from very high around some craters to intermediate and low. Surface appears generally flat; relief not determinable on photographs. Representative area: 5° S., 62°. *Interpretation:* Mostly cratered and intercrater plains materials; may include some smooth plains and rough terra deposits

TERRA MATERIALS

thl HILLY AND LINEATED TERRA MATERIAL—Rugged hills 5-10 km wide and 0.1-1.8 km high, narrow linear troughs, crater rims broken into rings of hills and depressions. Seen only near 25° S., 22°; maximum development south of Kuiper quadrangle. *Interpretation:* Structurally modified terrain antipodal to the Caloris Basin or peripheral to large impact basin beyond terminator

tr ROUGH TERRA MATERIAL—Very rugged, topographically high and fresh surface with numerous large- and medium-size young craters; overlaps and is embayed by smooth plains material. Representative areas: Northeast and southeast corners of quadrangle. *Interpretation:* Largely ejecta from young large craters that cannot be mapped separately. Highly scoured by secondary impacts that formed grooves and chains

CRATER AND BASIN MATERIALS

Craters are assigned to five morphologic categories (c_1, c_2, c_3, c_4, c_5), which ideally reflect their degradational state and relative age. Craters less than 30 km across are not mapped. All craters are thought to have formed by impact

cu CRATER MATERIAL, UNDIVIDED—Materials of craters too poorly resolved for relative age classification

c_5 CRATER MATERIAL—Forms floor, rim, and wall of fresh-appearing craters. Sharp, rugged, complete rim crest; walls typically terraced; well-defined continuous field of relatively crisp secondary craters; bright rays or crater materials superposed on all other craters

cp_5 CRATER PEAK MATERIAL—Single or multiple rugged peaks near center of crater

cr_5 CRATER RADIAL RIM MATERIAL—Grooved and ridged material extending outward from raised rim as lineated apron with many secondary craters

sc_5 SECONDARY CRATER MATERIAL—Shallow, circular to elongate craters, commonly overlapping, alined in chains or clusters

c_4 CRATER MATERIAL—Similar to c_5 craters but less sharp rim crest and slightly modified wall terraces; very few superposed craters

cp_4 CRATER PEAK MATERIAL—Same as cp_5 except occurs within c_4 craters

cr_4 CRATER RADIAL RIM MATERIAL—Same as cr_5 except surrounds c_4 crater materials

sc_4 SECONDARY CRATER MATERIAL—Same as sc_5 except secondary from c_4 craters

c_3 CRATER MATERIAL—Craters and basins with modified or rounded but intact rims; field of secondary craters present around larger craters but less well developed than around c_4 and c_5 craters. Moderate number of superposed craters

cpr_3 CRATER PEAK OR RING MATERIAL—Central peak or moderately rugged ring of massifs in center of basins

cr_3 CRATER RADIAL RIM MATERIAL—Same as around younger craters but discontinuous or less well preserved

sc_3 SECONDARY CRATER MATERIAL—Secondary craters surrounding larger c_3 craters and basins

c_2 CRATER MATERIAL—Shallow flat-floored craters and basins with low rims. No visible secondaries, many superposed craters

cpr_2 CRATER PEAK OR RING MATERIAL—Moderately rugged ring of massifs in center of large craters or basins

cr_2 CRATER RADIAL RIM MATERIAL—Discontinuous or narrow apron around large c_2 basins

c_1 CRATER MATERIALS—Craters or basins with extremely low or discontinuous rims

cpr_1 CRATER PEAK OR RING MATERIAL—Low, discontinuous, raised rings in center of largest c_1 craters

cpu CRATER PEAK MATERIAL, UNDIVIDED—Central peaks and high-albedo material in center of cu craters

scu SECONDARY CRATER MATERIAL, UNDIVIDED—Material of alined chains of craters of unknown age

(cpr_3) Symbol in parentheses where concealed by mapped younger deposits

Contact—Dotted where concealed. West of 50°, poor illumination results locally in dashes where approximately located or queries where doubtful

Fault—Ball and bar on downthrown side

Ridge in plains material—Symbol on ridge crest

Gentle rounded scarp—Line marks base; barb points downslope. May be lava flow front or fault scarp under surficial cover

Irregular scarp—Line marks top; hachures point downslope

Lineament, topographic or tonal

Depression, rimless

Crater rim crest—Hachures point down crater wall

Crater rim crest—Greatly subdued or buried

Ridge crest of multiringed basins

Bright ray material—Plumose streaks or halos on and around some c_5 craters. Visible only at high-sun angle.

INTRODUCTION

The Kuiper quadrangle, located in a heavily cratered region of Mercury, includes the young, 55-km-diameter crater Kuiper (11° S., 31.5°), which has the highest albedo recorded on the planet (Hapke and others, 1975), and the small crater Hun Kal (0.6° S., 20.0°), which is the principal reference point for mercurian longitude (Davies and Batson, 1975). Impact craters and basins, their numerous secondary craters, and heavily to lightly cratered plains are the characteristic landforms of the region. At least six multiringed basins ranging from 150 km to 440 km in diameter are present. Inasmuch as multiringed basins occur widely on that part of Mercury photographed by Mariner 10, as well as on the Moon and Mars, they offer a potentially valuable basis for comparison between these planetary bodies.

Basic information about the planetary surface of the Kuiper quadrangle is provided by three sequences of high-quality photographs designated Mercury I, II, and III, obtained during the incoming phases of three encounters of the Mariner 10 spacecraft with Mercury. Mercury I includes 75 whole-frame photographs of the Kuiper quadrangle; Mercury II, 13 whole-frame photographs; and Mercury III, 70 quarter-frame photographs. The photographs include 19 stereopairs in the southern part of the quadrangle. For examples of Mariner 10 photography, see Davies and others (1978). The most distant of the photographs was taken at an altitude of 89,879 km, the closest at an altitude of 7,546 km. Resolution, therefore, varies widely but ranges from about 1.5 to 2.0 km over most of the area. A wide range (more than 50°) of both viewing and solar illumination angles precludes a high degree of mapping consistency. The easternmost 10° of the quadrangle is beyond the evening terminator. A low angle of solar illumination and a high viewing angle make possible discrimination of topographic detail near the terminator. Higher angles of solar illumination and lower viewing angles make it increasingly difficult to discern topographic variations to the west. Many geologic units cannot be specifically identified because of unfavorable viewing geometry west of approximately 55°. Thus, mapping reliability decreases westward.

Mapping methods and principles are adapted from those developed for lunar photogeologic mapping (Wilhelms, 1970, 1972; Wilhelms and McCauley, 1971). Map units are distinguished on the basis of topography, texture, and albedo and are ranked in relative age on the basis of superposition and transection relations, density of superposed craters, and sharpness of topography. Because of the lack of a widespread, easily identifiable stratigraphic datum on this part of Mercury, a morphologic classification of crater and basin materials was the basis for determining relative ages of many materials. A photomosaic map of the best available photographs aided greatly in geologic interpretation and mapping.

STRATIGRAPHY

The rock units are subdivided into three major groups: plains materials, terra materials, and crater and basin materials. The plains and smooth terra units are considered to be volcanic in part, and thus may have a different origin from the impact breccias and churned regolith forming the rough terra and crater deposits.

The oldest rocks exposed in the quadrangle are the intercrater plains material (unit pi) and the rims of the oldest craters and basins. Collectively, these rocks form a relatively subdued terrain of moderate relief. They are similar to some of the rolling and hilly terra and hilly and pitted materials in the southern lunar highlands, particularly in the Purbach (Holt, 1974) and Tycho (Pohn, 1972) quadrangles. The intercrater plains unit is commonly marked by the soft outlines of numerous overlapping secondary craters producing a subdued hummocky texture. It is gradational in places with cratered plains material (unit pc), which forms flat, densely cratered surfaces similar to pre-Imbrian plains on the Moon (Wilhelms and McCauley, 1971; Scott, 1972). Although both the cratered and intercrater plains deposits are interpreted to be volcanic, the latter has been highly degraded by repeated impacts over a longer period of time. Much of its surface is probably covered by a relatively thick regolith of reworked impact breccias.

The cratered plains material is relatively flat with broad ridges and lobate scarps that in places resemble those of some of the lunar maria. It is difficult to obtain reliable crater counts on this unit because many secondary craters cannot be distinguished from primary craters. Cratered plains materials embay craters in classes c_1 to c_3; they may represent lava flows extruded after an initial phase of impact flux. The albedo of the cratered plains is intermediate compared to that of other mercurian units, but higher than that of the lunar maria, and may reflect lower iron and titanium content (Hapke and others, 1975).

The youngest rock units consist of rough terra and smooth plains materials. Rough terra occurs as overlapping and intermixed ejecta blankets around clusters of large young craters in the eastern part of the quadrangle. The relief here appears to be higher than elsewhere in the map area, and the occurrence of dense arrays of fresh secondary craters produces a coarsely textured, hummocky surface at a scale of about 10-20 km. The effect of roughness is high-lighted by the low-sun illumination angle. Ordinarily, rough terra material would be subdivided and mapped as individual ejecta blankets around and belonging to particular craters. In this eastern region, however, the closely grouped craters have about the same age, and it has not been possible to distinguish the boundaries between their aprons in many places.

Smooth plains material covers the floors of numerous craters in all age classifications. Its surface is scoured by secondary craters from classes c_4 and c_5 craters at many places in the eastern part of the quadrangle and, within the crater Homer (1° S., 37°), by secondaries from the class c_3 craters Titian (3° S., 42°) and Handel (4° N., 34°). Thus the smooth plains unit may have a relatively wide age range. Like the cratered plains, it exhibits lobate scarps and few mare-like ridges, but these are generally smaller than those of the cratered plains and more nearly resemble those of the lunar maria. Although crater counts are more reliable because there are fewer secondaries than in the cratered plains, resolution is a serious constraint to developing crater counts on the relatively small tracts of smooth plains. Preliminary counts made on a few of the more extensive occurences of smooth plains show a cumulative crater frequency of about 7.5 x $10^2/10^6$ km^2 for craters larger than approximately 2.5 km. This frequency is comparable to that of the lunar maria near the Apollo 11 landing site (Greeley and Gault, 1970; Neukum and others, 1975; Meyer and Grolier, 1977). Like that of the cratered plains, the albedo of the smooth plains is intermediate compared to other units on Mercury (Hapke and others, 1975) but is relatively high compared to that of the mare basalt on the Moon.

A few patches of very dark material occur in the western part of the quadrangle where the sun angle is high and albedo contrasts are enhanced. The largest of these dark patches is apparently superposed on the bright rays of a c_5 crater and is therefore very young.

CRATERS AND BASINS

Craters are ubiquitous features of the mercurian surface. For the purpose of mapping, a five-fold morphologic classification of craters (fig. 10 in McCauley and others, 1981) is the basis for determining their relative ages. The youngest craters (c_5) have sharp rim crests, textured ejecta blankets, and a well-defined field of secondary craters. Under favorable lighting conditions, the youngest craters exhibit bright rays superposed on all older materials. Older craters have increasingly degraded rims and lower relief and have lost their secondary crater fields. The major differences between mercurian and lunar craters are apparently related to the greater gravitational acceleration and the higher impact velocities on Mercury. Continuous ejecta deposits are less extensive, and secondary craters are more sharply defined and clustered nearer their primary crater. Also on Mercury, accentuated secondary craters form prominent crater chains radial to large craters.

Craters within the Kuiper quadrangle increase in complexity as they increase in size from simple bowl-shaped craters to complex craters with central peaks to multiringed basins. Kuiper (11° S., 31.5°) is a moderate-size crater with a central peak cluster; Brunelleschi (9° S., 22.5°) exhibits an incomplete ring of peaks; and Rodin (22° N., 18°) is a well-developed double-ringed basin. These three craters are mercurian counterparts in morphology to the lunar craters Copernicus, Compton (or Antoniadi), and Schrodinger. All craters larger than about 35 km diameter and basins are filled to some extent with plains materials, and exposed rims of partly buried craters within the basins indicate that the fill is about 700 to 1000 m thick (De Hon and Waskom, 1976).

Six basins ranging in age from c_1 to c_3 were formed during the waning stages of high-impact flux when the surface was virtually saturated with craters and basins. Later cratering history records a decreasing impact flux: of craters larger than 50 km diameter, 42 are classed as c_3; 19 craters are assigned to c_4; and 9 craters are c_5. There is also a decrease in the size of the largest crater or basin formed in each age class from c_2 to c_5.

STRUCTURE

Structural features are sparse or unresolved in this part of Mercury. The Kuiper quadrangle apparently has none of the scarps that occur elsewhere on the planet that have been interpreted as high-angle reverse faults (Strom and others, 1975). The most prominent structures are the rings associated with some large craters or basins, faults that transect crater floors, and lobate scarps and ridges in the plains materials. Most of the faults and scarps that transect crater floors clearly delineate crater-filling materials standing at different levels, and in at least two craters (19° S., 31°; 16° N., 30°), the traces of the faults on the crater walls indicate that the faults have normal displacements. A few faults cut intercrater areas and trend generally northwest or northeast (Scott and others, 1976).

Ridges are broader than many lunar mare ridges and are confined largely to the cratered plains materials. Antoniadi Dorsum, which is a well-developed broad ridge north of the Kuiper quadrangle, is less well developed at its south end and appears in this quadrangle as an irregular scarp. A number of linear depressions superficially resemble grabens but are chains of overlapping secondary craters, for example, Goldstone Vallis (15° S., 32°) and Haystack Vallis (5° N., 46°).

GEOLOGIC HISTORY

The interpretable geologic history of the Kuiper quadrangle is primarily a record of decreasing meteoroid flux during which large craters and basins formed and plains materials were deposited. A decreasing rate of crater production is indicated by progressively fewer craters in each successively younger crater class. Approximately half of the mapped area contains a high density of craters and multiringed basins formed by the intense early bombardment. It is doubtful that any primary crustal material has been preserved without brecciation and redistribution by repeated impacts. The present crater population represents only the craters surviving at the end of the stage of highest meteoroid flux. As the impact flux decreased, cratered plains materials of possible volcanic origin were deposited in broad, low-lying areas, flooding, embaying, or partially burying preexisting craters. The youngest multiringed basins (Renoir, Rodin, and the unnamed basin at 15° S., 15°) formed near the end of this stage (about c_3 time), as did the Caloris Basin on the opposite side of the planet (McCauley and others, 1981; Schaber and McCauley, 1980). Craters that formed still later during the period of low impact rates are well preserved. During this late stage, smooth plains materials were deposited in basins, craters, and localized low areas and have low crater density. The youngest craters are sharp rimmed with bright rays.

The relatively small size of Mercury, its lack of atmosphere, and the cratered nature of its surface invite comparison with the Moon. The geologic histories of the two bodies are similar. Both surfaces record a decreasing impact flux. The cratering history of Mercury was concurrent with episodes of lava flooding (cratered plains) that may have obliterated some basins and flooded large areas in a manner similar to the mare filling on the Moon. Bright-rayed craters, such as Kuiper, mark the youngest events similar to Copernican craters on the Moon; some dark patches along the west margin of the quadrangle may represent late volcanism.

Some differences between the Moon and that part of Mercury observed in this quadrangle may be more apparent than real. Apparent differences may be the result of resolution of the imaging system, and small viewing and illumination angles that do not allow inspection of the surface under varied conditions. Real differences may be the result of Mercury's size, gravitational field, proximity to the Sun, internal composition and structure, or timing of major volcanic episodes relative to the decrease in impact craters. Surface differences include the preservation of secondary craters around older craters and basins, and the absence of recognizable textured and lineated ejecta blankets such as those surrounding the Imbrium and Orientale Basins on the Moon. Possible differences in volcanic features include the absence of widespread dark mare-type deposits, volcanic domes and cones, and sinuous rilles. Whereas plains and terra divisions may be distinguished on Mercury, the distinct lunar dichotomy of mare and highlands is not present on that half of Mercury observed by Mariner 10.

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