GEOLOGIC MAP OF THE BEETHOVEN (H-7) QUADRANGLE OF MERCURY

By
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DESCRIPTION OF MAP UNITS

[Cumulative crater counts (N_c) made for craters ≥5 km in diameter per square kilometer shown for some map units]

PLAINS MATERIALS

ps **Smooth plains material**—Occurs within c_4 and older craters, locally within low intercrater areas. Craters of c_5 age superposed. Surface smooth, flat; sparsely cratered with few ridges. N_c=7.8 X 10^{-5} ± 4.5 X 10^{-5}. *Interpretation:* Volcanic and impact melt materials; clastic ejecta from primary and secondary craters

psi **Intermediate plains material**—Forms relatively smooth, slightly hummocky surfaces within large intercrater areas and in floors of c_3 and older craters. More densely cratered than smooth plains unit. N_c = 1.1 X 10^{-4} ± 3.1 X 10^{-5}. Mapped as cratered plains material to east in Kuiper quadrangle (De Hon and others, 1981). *Interpretation:* Same as for smooth plains material but older; deposited over larger areas

pi **Intercrater plains material**—Forms rough, planar, highly cratered surface over western part of map area; grades eastward into plains and terra material, undivided. Embays and buries parts of Beethoven basin rim material (unit brl) in places, but in others is overlapped by the rim material. N_c = 2.3 X 10^{-4} ± 4.4 X10^{-5}. *Interpretation:* Crater and basin ejecta, volcanic flows, possible pyroclastic deposits; many partly buried crater rims contribute to surface roughness

ptu **Plains and terra material, undivided**—Continuation of same unit from Kuiper quadrangle (De Hon and others, 1981) to east; mapped there and in eastern half of Beethoven quadrangle where high sun angle prevents good image quality. Transitional westward with intercrater plains material. Surface appears generally flat, highly cratered, with lobate scarps and broad ridges. N_c = 2.3 X 10^{-4} ± 3.8 X 10^{-5}. *Interpretation:* Similar to intercrater plains material and to some intermediate plains material

BASIN MATERIALS

[Basins are interpreted to have been formed by impact]

brl **Beethoven basin rim material**—Radially lineated and grooved ejecta blanket covering rim of Beethoven basin and extending generally outward from it; extensive on north and east sides. Craters of c_2 and younger age superposed; abundant clusters of secondary craters 10 to 20 km across. N_c = 1.6 X 10^{-4} ± 3.8 X 10^{-5}

rrl **Raphael basin rim material**—Extends outward from rim of Raphael basin. Similar to Beethoven rim material; abundant clusters of craters 10 to 15 km across. N_c=1.1 X 10^{-4} ± 3.0 X 10^{-5}

CRATER MATERIALS

[Craters are divided on the basis of their morphologic characteristics into five categories (c_1, oldest, to c_5, youngest), which reflect their degradational state and, ideally, their relative age (McCauley and others, 1981). Craters less than about 30 km in diameter are not mapped, excepting rayed craters of c_5 age. Rim, wall, and floor materials are generally not mapped separately, but rim-crest symbol divides exterior and interior crater deposits. All craters are interpreted to have been formed by impact]

c_5 **Material of very fresh craters**—Forms floor, rim, and wall of fresh-appearing, sharp-rimmed, rayed craters. Highest albedo in map area; haloes and rays may extend many crater diameters from rim crests. Superposed on all other map units. Generally smaller and fewer than older craters. Elsewhere on Mercury where sun angle is lower, some larger, very fresh appearing craters have been mapped as c_5, but in this quadrangle craters of this type cannot be separated from c_4 craters

c_4 **Material of fresh but slightly modified craters**—Similar in morphology to c_5 craters but without bright haloes or rays; sharp rim crests; continuous ejecta blankets; very few superposed secondary craters (unit cs). Floors consist of crater or smooth plains materials

c_3 **Material of modified craters**—Rim crest continuous but slightly rounded and subdued. Ejecta blanket generally less extensive than those of younger craters of similar size. Superposed craters and rays common; smooth plains and intermediate plains materials cover floors of many craters. Central peaks more common than in c_4 craters, probably because of larger average size of c_3 craters

cf_3 **Floor material of c_3 craters**—Hummocky, rough-textured material forming floor deposits in crater Vālmiki (lat 23° S., long 142°)

cr_3 **Rim material of c_3 craters**—Forms rough blanket around crater Vālmiki and crater Haydn in Discovery quadrangle (Trask and Dzurisin, 1984) adjacent to southeast. Superposed crater chains mapped as secondary crater material, undivided

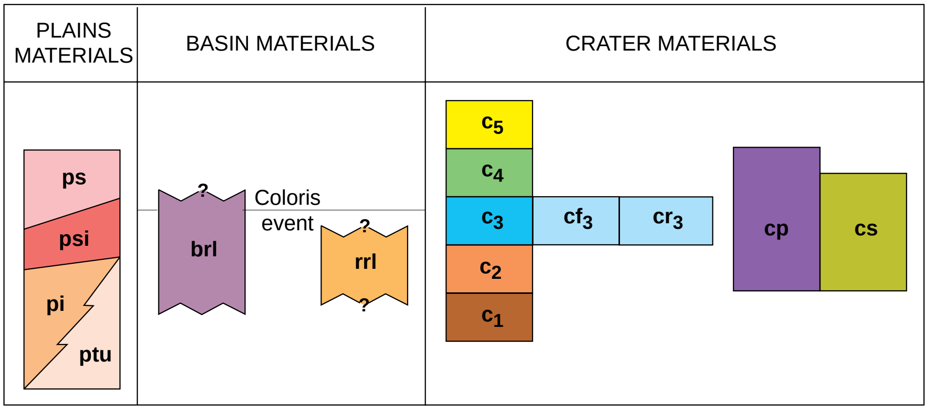
c_2 **Material of subdued craters**—Low-rimmed, relatively shallow craters, many with discontinuous rim crests. Floors covered by smooth plains and intermediate plains materials. Includes rim material of Raphael basin and several double-ring craters. Crater density of ejecta blankets similar to that of intermediate plains material: $N_c = 1.1 \times 10^{-4} \pm 3.0 \times 10^{-5}$ (Raphael basin rim material); $Nc = 1.3 \times 10^{-4} \pm 4.3 \times 10^{-5}$ (Mark Twain ejecta blanket, lat 11° S., long 138°)

c_1 **Material of degraded craters**—Similar to c_2 crater material but more deteriorated; many superposed craters

cp **Central peak or ring material**—Occurs in c_2 to c_4 craters as single hills or partial rings rising above crater floors near their centers. *Interpretation:* Precrater brecciated rocks uplifted and deformed at time of impact

cs **Secondary crater material, undivided**—Occurs throughout quadrangle as aligned chains of craters of unknown age. Those mapped probably originate from moderate- to large-size craters within and outside quadrangle. In places parent or source crater can be inferred by radial alignment of one or more chains to crater center

CORRELATION OF MAP UNITS



Contact—Dashed where poorly defined

Fault or graben—Ball on downthrown side

Scarp—Line marks base; barb points downslope

Ridge—Symbol on ridge crest

Trough—Barbs point downslope

Crater rim crest

Crater rim crest—Greatly subdued or buried

Crestline of Beethoven basin

Bright ray or halo material around or emanating from c5 craters—Interpreted as fresh ejecta

Area of abnormally low albedo

INTRODUCTION

The Beethoven quadrangle is located in the equatorial region of Mercury, in the center of the imaged area. Most pictures of the quadrangle were obtained at high sun angles as the Mariner 10 spacecraft receded from the planet. Geologic map units are described and classified on the basis of morphology, texture, and albedo, and they are assigned relative ages based on stratigraphic relations and on visual comparisons of the density of superposed craters. Crater ages are established by relative freshness of appearance, as indicated by topographic sharpness of their rim crests and degree of preservation of interior and exterior features such as crater floors, walls, and ejecta aprons. Generally, topography appears highly subdued because of the sun angle, and boundaries between map units are not clearly defined.

Impact craters larger than about 250 km are referred to as basins. Unlike many basins on the Moon, however, the two obvious basins in the quadrangle, Beethoven (610 km in diameter) and Raphael (320 km in diameter), are not multiringed, whereas well-developed rings encircle many craters of lesser diameters (Trask, 1976). Remnant ejecta blankets around parts of the Beethoven and Raphael basins are subdued in appearance and their margins poorly defined in places. However, where they can be recognized, these extensive aprons allow a generalized regional stratigraphic sequence to be determined. A third basin, extremely subdued but probable, is centered at lat 0°, long 130°.

Images in the northeastern part of the quadrangle are very poor to unusable. This area therefore contains blank patches or only a few crater outlines and mapped materials. Another difficulty in mapping is the poor match in topographic bases between Beethoven and adjacent quadrangles. Mismatches are especially common along the borders with the Kuiper and Discovery quadrangles to the east and southeast.

STRATIGRAPHY

PLAINS MATERIALS

Major divisions of rock units in the quadrangle are (1) plains materials and (2) crater and basin materials. Surfaces of the plains units range in morphology from relatively level but rough to nearly flat and smooth; the latter terrain has intermediate albedo like that of the Cayley Formation or older maria on the Moon. Plains materials are identified in part by surface texture and their relative ages determined by density of superposed craters. Intercrater plains material (unit pi), one of the two oldest plains units, was originally described by Trask and Guest (1975). It covers large areas in the western, central, and southeastern parts of the quadrangle. There, as in other regions of Mercury (Malin, 1976), its surface reveals the outlines of many buried crater rim crests and knobby remnants of an older resurfaced terra. This unit has been scoured by many secondary craters that have formed overlapping chains and troughs that contribute to its hummocky texture. The intercrater plains unit is inferred to consist of crater and basin ejecta deposits, volcanic flows, and possible pyroclastic deposits that have partly resurfaced and smoothed older, highly cratered, crustal rocks. The unit appears to be gradational laterally eastward with plains and terra material, undivided, and vertically with intermediate plains material. The intercrater plains material is probably about the same age as the ejecta blanket around Beethoven basin (unit brl): both units have a high crater density. That the plains unit is younger than Beethoven may be indicated in some areas where the basin’s ejecta blanket appears to be partly obscured by the overlap or embayment of plains material. Spudis and Prosser (1984) have suggested that Beethoven may possibly be late c_3 in age or as old as early c_2.

The age of the plains and terra material, undivided (unit ptu) is probably equivalent to that of the intercrater plains material, and to at least part of the intermediate plains material, though it was not found in contact with the latter. The plains and terra unit, occurring in the central and eastern parts of the quadrangle, was originally mapped to the east in the Kuiper quadrangle (De Hon and others, 1981). The term was there applied where differences in image quality prevent clear distinctions between plains and terra materials. The name was adopted in the Beethoven quadrangle for the same reason. The unit intergrades to the west and south with intercrater plains material and is interpreted to be of the same origin and composition.

The intermediate plains material (unit psi) and smooth plains material (unit ps) probably also consist of mixtures of relatively fine crater ejecta and volcanic materials that appear to form a continuous sequence. Both units are thicker than the intercrater plains unit. The intermediate plains material is widespread in intercrater areas in the west half of the quadrangle and fills floors of older craters and basins in the southern part. Smooth plains material (unit ps), the youngest plains unit, occurs as scattered patches in low areas and covers the floors of many craters of c_4 age and older. In some crater floors, especially smaller ones, differentiation between smooth plains and intermediate plains materials is difficult and the choice becomes arbitrary.

Aside from a few small patches of dark material, and areas covered by bright rays (stippled map pattern) around and emanating from c_5 craters, all plains units and the exterior rim materials of many craters have albedos in the intermediate range. Collectively, these materials impart a homogeneous appearance to the surface of the planet that is unlike the contrast in bright highlands and dark maria of the Moon.

No terra material similar to that in the Kuiper quadrangle (De Hon and others, 1981) was recognized in the Beethoven quadrangle. Its absence may be due, in part, to fewer clusters of large young craters whose coalesced ejecta blankets could have yielded the coarsely textured, rough surfaces that characterize the unit in the Kuiper area. Also, the visible effect of roughness is diminished by the higher sun angle at which the Beethoven images were acquired.

BASIN AND CRATER MATERIALS

Coarsely lineated ejecta blankets from Beethoven and Raphael basins dominate the southern part of the map area. The crater wall of Beethoven is buried by its ejecta blanket (unit brl) and by plains materials (units pi and psi). Although the ejecta blankets from both basins are extensive, they are highly asymmetrical and deeply embayed in places by intercrater plains and younger plains units. These embayment relations, together with the discontinuous and subdued appearance of the rim crests and interior walls of the basins, suggest that they are relatively old impact structures. Morphologic appearances may be misleading on Mercury, however, because of the planet's high temperature and gravity field compared with, for example, those of the Moon. Both of these conditions may promote, particularly on large structures (Trask, 1976), more rapid isostatic adjustments that would be expressed by subdued topography and the premature "aging" of once-large topographic features. Crater counts, on the other hand, tend to support observed stratigraphic relations. (See Description of Map Units.)

In addition to the large single-ringed basins of Beethoven and Raphael, at least eight double-ringed craters exceeding 100 km in diameter occur in the quadrangle. These craters range in age from c_1 to c_3 and, on a minor scale, their ejecta blankets provide stratigraphic horizons useful for the relative dating of material units in their vicinity. Two of the youngest of the double-ringed craters, Durer (lat 22° N., long 119°) and Vivaldi (lat 14° N., long 86°), have prominent and nearly continuous inner rings whose diameters measure about half that of their outer rings. Unlike some of the lunar multiringed structures, no vestiges of additional rings are apparent around these craters.

Central peaks are common within craters of c_3 and c_4 age, rare in craters of c_2 age. Their origin may be genetically related to the inner rings of larger craters and basins. Crater floors are underlain by a zone of shattered and brecciated material formed by the shock wave resulting from impact. Crater-rim material consists of decompressed ejecta from the impact, whereas central peaks were probably formed by the converging flow of slump material from the crater walls (Shoemaker, 1981). If a crater was sufficiently large, the converging flow resulted in an inner ring rather than a central peak. An alternative model for central ring or peak formation was discussed by Melosh (1983), who suggested that they form as a result of rebound of fractured material analogous to the jet produced by a stone dropped into water. Depending on the size of the crater, the result is either a central peak or an inner ring. The limiting crater size for central peaks has been defined by Guest and others (1979, p. 88) as about 150 km. This size limit seems to be generally applicable in the Beethoven quadrangle with the exception of the ringed crater Judah Ha-Levi (lat 11° N., long 109°), which has an inner rim-crest diameter of about 80 km. Although this crater appears to have two rings, its inner ring structure is morphologically fresher than the outer ring, and it may have been formed by a separate and later impact.

Craters less than about 30 km in diameter were not mapped except for those that are rayed and those occurring in chains and clusters satellitic to larger craters and basins. These satellitic or secondary craters (unit cs) are not distinguished as to relative age or origin. (However, near the southwest map corner, elongate chains are radial to their parent crater Vālmiki). In general, secondary craters appear topographically fresher and occur closer to their primary sources than do their lunar counterparts. This effect is probably due to the fact that the higher gravity field on Mercury compared to the Moon has resulted in higher impact velocities for crater ejecta (Gault and others, 1975; Scott, 1977).

STRUCTURE

Neither faults nor scarps that are possibly associated with faults or monoclinal folding appear to be common in the Beethoven quadrangle, possibly because of the high sun elevation. The longest and most prominent of these structures occur in the plains and terra material, undivided, in the southeast quadrant of the map area. There, a series of prominent scarps extends northeast from near lat 10° S., long 95° to lat 4° S., long 86°, over a distance of about 400 km. The inner ring of crater Durer appears to be slightly offset on the north side by a small normal or strike-slip fault.

Troughs and ridges are present throughout the quadrangle. Where the troughs are not clearly radial to crater or basin centers, they may be grabens; however, in most places they are difficult to distinguish from linear gouges produced by impact ejecta at low-angle ballistic trajectories. Some ridges resemble those on the lunar maria, but generally they are less sharply defined. Ridges interpreted to be buried rim crests of two ancient basins are partly visible almost due north of Beethoven basin; the probable centers of the basins are near lat 11° S., long 127° and lat 2° N., long 124°.

GEOLOGIC HISTORY

Geologic evidence for the reconstruction of the evolutionary history of Mercury is less complete than for the Moon and Mars, for which orbiting spacecraft and landers have provided total or near-total coverage and high-resolution images. However, available data allow certain parallels to be drawn with respect to the bombardment and accretionary histories of the three bodies. The geologic record shows a period of decreasing meteoroid flux on all three, wherein the basins and large craters formed early in their crustal evolution were superseded by impacts of progressively smaller size. The relative paucity of mappable c_5 craters in the Beethoven quadrangle is indicative of the decreasing crater-production rate in the younger crater classes. The low density of small craters in the oldest class, c_1, results from their destruction by impacts and obscuration by ejecta and volcanic material over a long period of mercurian history.

The intercrater plains and younger plains materials probably have mixed origins, and they consist of both volcanic and impact ejecta-related deposits. The plains materials accumulated mostly in low-lying areas and have buried or partly buried older craters and surfaces. Their relative ages and thicknesses are reflected by the number of craters visible on their surfaces: where crater densities are high, the plains material is relatively old or thin; low crater densities indicate relatively thick, young deposits. Where superposed craters can be distinguished from partly buried craters, relative ages of the plains units can be established. Crater counts (Description of Map Units) indicate that the intercrater plans unit, whose crater density is twice that of the intermediate plains unit, is significantly older.

Whether the mercurian plains materials are analogous to volcanic flows of the lunar maria is unknown. In this quadrangle, the former lack many characteristics of mare materials, including low albedo and strong albedo contrasts with other units, lobate flow fronts, sinuous rilles, and numerous “wrinkle”-type ridges and domes with summit craters. Possibly the plains units on Mercury are similar to the Cayley Formation on the Moon and consist largely of finely divided ejecta materials. Whatever the origin and composition of the plains units in the Beethoven quadrangle, they represent late stages in the crustal evolution of this region.

Other differences between the Moon and that part of Mercury observed in this quadrangle are the absence in Beethoven of distinct highlands and lowlands, as well as the preservation in the quadrangle of secondary crater chains around older craters and basins (Scott, 1977).

The geologic history of Mercury has been summarized by Guest and O’Donnell (1977), Davies and others (1978), and Strom (1979).

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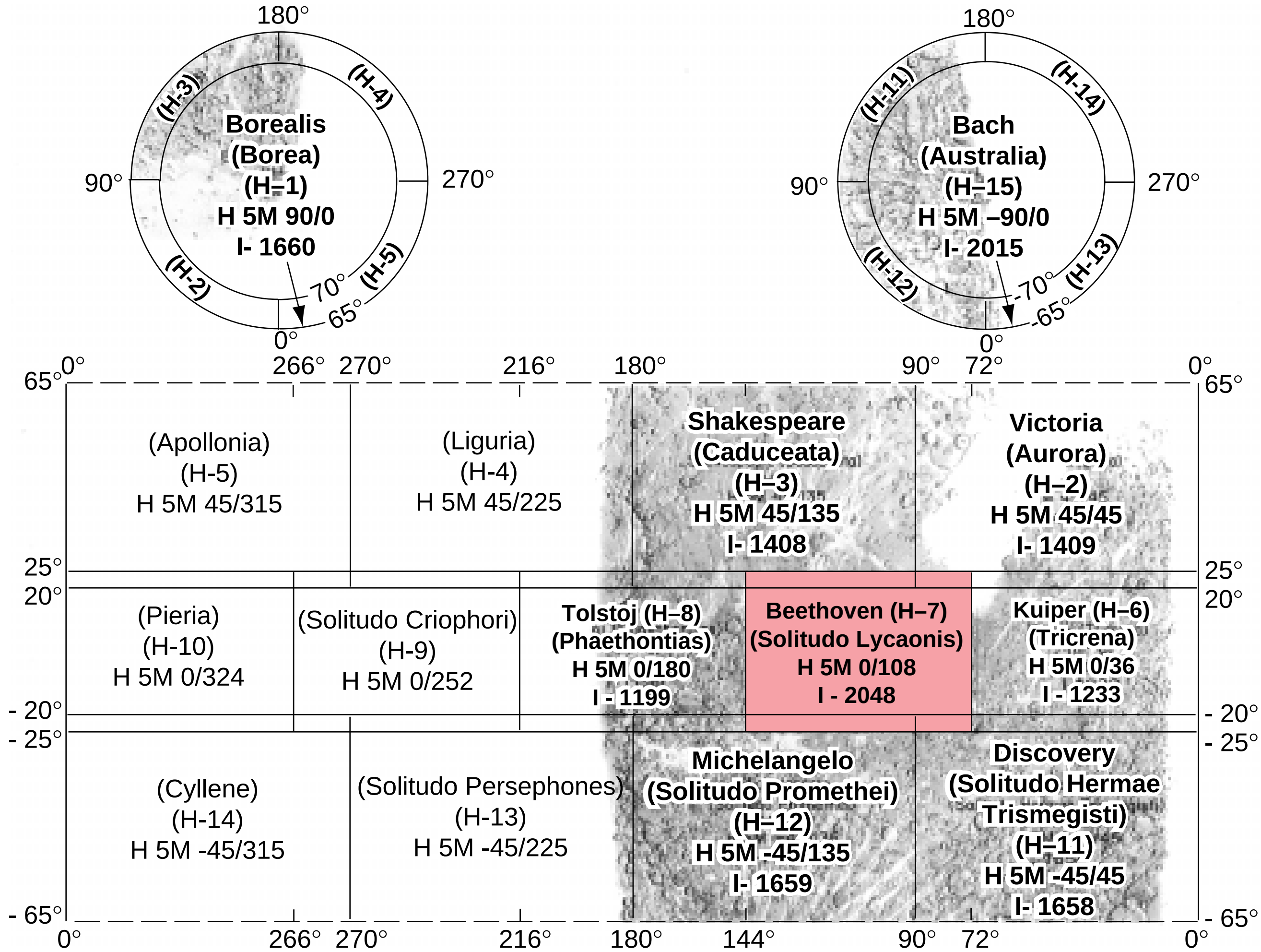
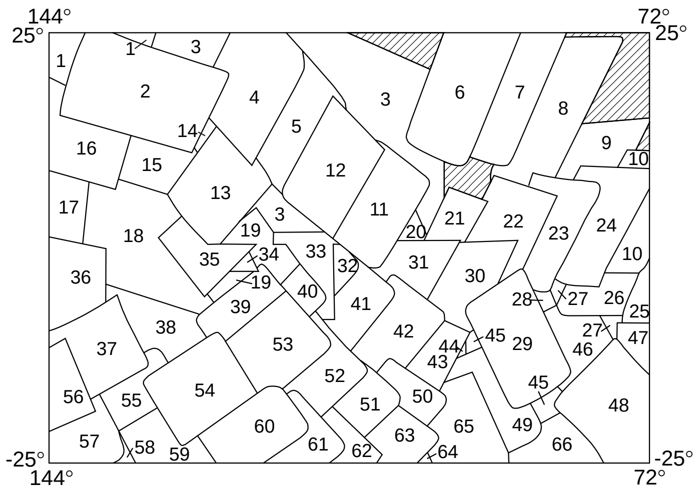


ARRANGEMENT OF MAP SHEETS ON MERCURY

The provisional name "Goethe" was changed to "Borealis," and the provisional name "Tir" was changed to "Tolstoj" by the International Astronomical Union in 1976 (IAU, 1977). These provisional names appeared on earlier editions of this index map and on the shaded relief map of Tolstoj (H–8) quadrangle. The number preceded by I refers to published geologic map.



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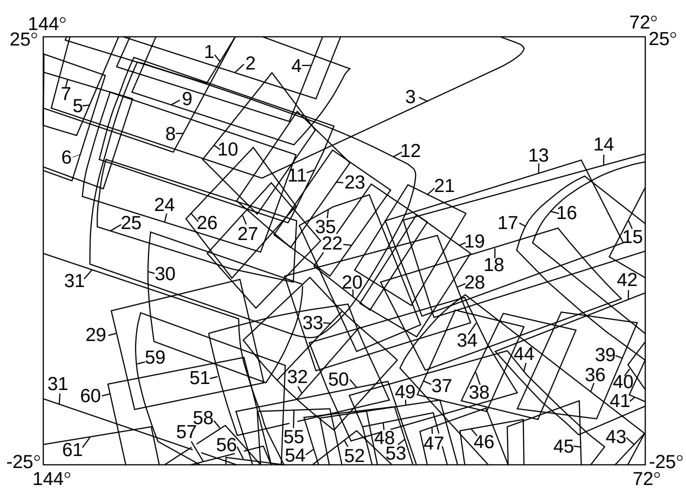
4	166786	26	166764	48	166639
5	166785	27	166585	49	166699
6	166768	28	166697	50	166799
7	166767	29	166692	51	166806
8	166766	30	166781	52	166807
9	166765	31	166782	53	166808
10	166770	32	166715	54	166816
11	166783	33	166696	55	166821
12	166784	34	166810	56	166828
13	166798	35	166804	57	166827
14	166792	36	000215	58	166826
15	000179	37	166822	59	166820
16	000183	38	000211	60	166815
17	000214	39	166809	61	166814
18	000210	40	166802	62	166813
19	166803	41	166794	63	166805
20	166694	42	166793	64	166642
21	166774	43	166780	65	166700
22	166773	44	166693	66	166640

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. Cross-hatched areas indicate no photo coverage on the mosaic.



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SUPPLEMENTAL SOURCE INDEX

The Mariner 10 pictures outlined above were used to provide additional detail on the map but were not used on the controlled mosaic.