Newell J. Trask and Daniel Dzurisin

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 the Tolstoj (H-8) quadrangle. The number preceded by I refers

to published geologic map.

1:5,000,000 GEOLOGIC SERIES **DISCOVERY QUADRANGLE** H 5M -45/45 G, 1984 I-1658 (H-11)

ATLAS OF MERCURY

CORRELATION OF MAP UNITS INTRODUCTION

DESCRIPTION OF MAP UNITS

of c₅ craters (FDS 27382). Moderate to low (0.13-0.16)

uniform albedo; surface smooth at all resolutions; very

rangle in relatively small patches within and between

craters (FDS 166668). Crater density $1.3 \times 10^{2} (>10)$

tracts and tracts near terminator do not show mottling

(FDS 166619). Very gentle rolling relief interrupted by

contacts with adjoining high ground. Interpretation:

Mostly volcanic; unequivocal volcanic vents and lava

flow fronts not observed; smaller patches (<50 km)

may be melted fallback or accumulations of loose debris

ERMEDIATE PLAINS MATERIAL-Occurs within c

density is higher than that of nearby smooth plains unit

and lower than that of nearby intercrater plains unit

(FDS 27428); also mapped as patches within intercrater

plains unit on basis of crater density; moderate albedo

and some patches of low albedo. Small pits and hills

rare to common. Gradational contacts with units of

adjoining high ground. Mapped as cratered plains material

in Kuiper quadrangle (De Hon and others, 1981) Inter-

pretation: Mostly volcanic; smaller patches (<50 km)

may be melted fallback or accumulations of loose debris

pooled in lows by secondary-impact events. Most

gently rolling ground between large craters and basins; especially extensive in northwestern part of quadrangle

where large c₁ and c₂ craters are rare (FDS 166653).

Albedo medium to low (0.13-0.17); crater density 3.0 to

are shallow and irregular in shape, and many occur in

strings and clusters, suggesting secondary-crater mor-

phology (FDS 27420). Mapped in part as rough terra

material in Kuiper quadrangle (De Hon and others,

1981) in area of overlap of northern part of Discovery

quadrangle. Interpretation: Volcanic materials of

regional extent; probably includes unmapped tracts of

RELIEF-FORMING MATERIALS

intermediate plains material that may be younger than

near northeast corner of quadrangle. Forms hills and

intervening hollows 5 to 10 km wide; hills are 0.1 to 1.8

km high (FDS 27422; 27463). Area cut by numerous

lineaments trending generally N. 50°-60° W.; some

lineaments consist of open-ended, coalescing scalloped

depressions. Preexisting crater rims broken into hills and

depressions like those on adjacent ground; no undeformed

within modified craters on or near hilly and lineated

material (FDS 27423). Forms level areas studded with

hummocks averaging 2 km in width; hummocks smaller

and farther apart than those of adjacent hilly and lineated

unit. Interpretation: Formed by same processes that

resulting in smaller and sparser hummocks; initial material

across that are roughly radial to c4 craters and grade

roughly radial to large c4 craters and basins

(FDS 27416)

(FDS 166646)

of high sun angle

plains; all flooded by plains units

outward to irregular, elongate, subdued satellitic craters

Material of rims, walls, and floors of subdued craters and

basins (FDS 166650) - Low, rounded rims and some

remnants of wall structures; flat floors, many filled with

plains materials; floor-wall boundary indistinct in many

intact rims, walls with discontinuous terraces, and discontinuous fields of satellitic craters (FDS 166671)

Material of radial-rim facies of subdued basins (FDS 27415) -

Irregular hummocks and depressions with vague radial

Material of small, highly subdued, elongate, and coalescing

craters roughly radial to large c3 craters and basins

Shallow, pan-shaped; no wall structure. Larger craters

and basins have flat floors and low but continuous rims bearing many smaller superposed primary and satellitic

craters; a few have low central peaks; one has inner concentric ring; all flooded by plains materials

basins and material of peak ring in crater Chekhov

coalescing craters and a few elongate hummocks, radial

to Raphael Basin, which is located to north in Beethoven

quadrangle (FDS 166640). Unit poorly defined because

craters roughly radial to large c₂ basin (FDS 166685)

laterial of nearly destroyed craters and basins (FDS 27419)-

Relatively large, flat-floored; extremely low or discon-

tinuous rims rising only slightly above surrounding

craters. Larger craters and basins have modified but

may have been intermediate plains unit

of seismic energy at the antipode to the Caloris Basin

craters and basins. Rare subsequent scarps and ridge

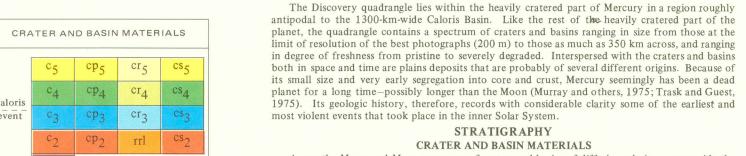
occurrences within craters are clearly younger than intercrater plains unit; tracts shown enclosed by intercrater

c₃ craters and basins (FDS 166675) where its crater

pooled in lows by secondary-impact events

PLAINS MATERIALS

may be volcanic, induced by impact



As on the Moon and Mars, sequences of craters and basins of differing relative ages provide the best means of establishing stratigraphic order on Mercury (Pohn and Offield, 1970; Stuart-Alexander and Wilhelms, 1975). Overlap relations among many large Mercurian craters and basins are clearer than those on the Moon. Therefore, as this map shows, we can build up many local stratigraphic columns involving both crater or basin materials and nearby plains materials. Over all of Mercury, the crispness of crater rims and the morphology of their walls, central peaks, ejecta deposits, and secondary-crater fields have undergone systematic changes with time. The youngest craters or basins in a local stratigraphic sequence have the sharpest, crispest appearance. The oldest craters consist only of shallow depressions with slightly raised, rounded rims, some incomplete. On this basis, five age categories of craters and basins have been mapped; the characteristics of each are listed in the explanation. In addition, secondary crater fields are preserved around proportionally far more craters and basins on Mercury than on the Moon or Mars, and are particularly useful in determining overlap relations and degree of modification. PLAINS MATERIALS

All low-lying areas and the areas between craters and basins in the Discovery quadrangle are

covered by broadly level, plains-forming material, except for small areas covered by the hilly and

lineated material and hummocky plains material described below. Tracts of plains materials range

in size from a few kilometers across to intercrater areas several hundred kilometers in width. This material is probably not all of the same origin. Strom and others (1975) and Trask and Strom (1976) cited evidence that many large areas of plains are of volcanic origin. Smaller tracts are more apt to be impact melt, loose debris pooled in low spots by seismic shaking (Schultz and Gault, 1975), or ejecta from secondary impacts (Oberbeck and others, 1977). The origin of many individual tracts must necessarily remain uncertain without additional information. Plains materials have been grouped into four units on the basis of both the density of superposed craters and the relation of each unit to adjacent crater and basin materials. These units are listed as follows from oldest to youngest. (1) Intercrater plains material (unit pi) is widespread, has a high density of small craters (5 to 15 km in diameter), and appears to predate most of the relatively old and degraded craters and basins, although some tracts of intercrater plains material than the intercrater plains unit and has a density of superposed small craters that is intermediate between those of the intercrater plains and smooth plains units. The intermediate plains material is most readily mapped on the floors of those c1, c2, and c3 craters and basins that are surrounded by intercrater plains material with a distinctly higher crater density (FDS 27428). Contacts between intercrater plains and intermediate plains units that occur outside mapped craters and basins are gradational and uncertain. In parts of the quadrangle, photographic resolution and lighting do not permit the intermediate plains unit to be separated from the intercrater plains or smooth plains units with a high level of confidence. (3) Smooth plains material (unit ps) occurs in relatively small patches throughout the quadrangle on the floors of c_4 and older craters and basins and in tracts between craters. More bright-halo craters occur on this unit than on either the intercrater plains or intermediate plains units. (4) Very smooth plains material (unit pvs) occurs on the

RELIEF-FORMING MATERIALS The Discovery quadrangle includes some of the most distinctive relief-forming material on the planet, the hilly and lineated terrain unit mapped by Trask and Guest (1975). The unit consists of a jumble of evenly spaced hills and valleys about equal in size. Most craters within this material appear to predate its formation, and their ages cannot be estimated: their rims have been disrupted into hills and valleys identical to those of the hilly and lineated unit; the floors of some of these degraded craters contain hummocky plains material (unit ph) that resembles the hilly and lineated unit, except that the hills are fewer and lower. The hilly and lineated unit and the enclosed hummocky plains unit appear to be relatively

floors of some of the youngest craters. In summary, a complex history of contemporaneous

formation of craters, basins, and plains is thus indicated by the mapping.

young; they may be the same age as the Caloris Basin. In addition, they lie almost directly opposite that basin on the planet. Both observations strengthen the suggestion that the hilly and lineated unit and the hummocky plains unit are directly related to the formation of Caloris (Schultz and Gault, 1975), possibly through the focusing of seismic waves at the antipodal point. STRUCTURE

Morphologically diverse scarps, ridges, troughs, and other structural lineaments are relatively common in the Discovery quadrangle. Dzurisin (1978) documented a well-developed pattern of linear lithospheric fractures in the quadrangle that predate the period of heavy bombardment. A dominant structural trend is recognized at N. 50°-45° W., and subsidiary trends occur at N. 50°-70° E. and roughly due north. Joint-controlled mass movements were most likely responsible for the fact that many craters of all ages have polygonal outlines, and some linear joints may have provided surface access for lavas that formed the intercrater plains. Evidence of the latter may be recorded by several linear ridges that may have been formed by lava accretion along linear volcanic vents (for example, Mirni Rupes at lat 37° S., long 40° W., FDS 27420). Planimetrically arcuate escarpments in the Discovery quadrangle cut intercrater plains and

crater materials as young as c_4 . These scarps are typically 100 to 400 km long and 0.5 to 1.0 km high, and they have convex-upward slopes in cross section that steepen from brink to base. More trend closer to north-south than to east-west. Discovery (lat 55° S., long 38° W.), Vostok (lat 38° S., long 20° W.), Adventure (lat 64° S., long 63° W.), and Resolution (lat 63° S., long 52° W.) Rupes are the most prominent examples in the quadrangle. Vostok transects and foreshortens the (thrust or high-angle reverse faults). Melosh and Dzurisin (1978) have speculated that both arcuate scarps and the global Mercurian lineament pattern may have formed as a result of simultaneous Planimetrically irregular scarps on the floors of many plains-filled craters and basins are the

youngest recognized structural features in the quadrangle, as they cut both the smooth plains and intermediate plains materials. Their occurrence inside only smooth-floored craters and basins suggests that the stresses responsible for their formation were local in extent, perhaps induced by magma intrusion or withdrawal beneath volcanically flooded craters. GEOLOGIC HISTORY

induced by tidal despinning most likely were sufficient to cause widespread fracturing. Melosh

Any reconstruction of Mercurian geologic history must include the inference that at an early time the planet was differentiated into a core and crust. Mercury has a weak magnetic field (Ness CRATER AND BASIN MATERIALS and others, 1976) coupled with high density. Both facts can most easily be accounted for by the The morphology of virtually all Mercurian craters and basins presence of an iron core, possibly liquid, roughly 4,200 km in diameter, overlain by a silicate crust a few hundred kilometers thick. The postulated volcanic origin of a substantial fraction of is comparable to that of lunar craters and basins, when allowance is made for differences in gravity on the two the Mercurian plains also implies a thick silicate crust, and thereby supports the existence of a bodies, indicating that Mercurian craters and basins almost large iron core (Murray and others, 1975). certainly formed by impact. Crater and basin materials are Early, rather than late, differentiation of Mercury is attested to by the compressional scarps

mapped according to their relative ages as determined by that are so clearly seen in the Discovery quadrangle. Segregation of the core must have released apparent degree of degradation and local overlap relation. large amounts of heat, which would have resulted in significant expansion of the crust (Solomon, The age classification is that of N. J. Trask in McCauley and 1976; Solomon and Chaiken, 1976). However, unambiguous extensional features (very rare on others (1981). Craters smaller than 30 km in diameter are the planet as a whole) are not seen in the Discovery quadrangle; only compressional scarps occur. Thus, core segregation occurred relatively early (before formation of a solid lithosphere) and was Material of rims, walls, and floors of very sharp rimmed followed by cooling and contraction, the last phases of which probably contributed to the formacraters (FDS 27382)-Flat floors, well-defined wall tion of arcuate scarps that predated the end of heavy bombardment (Dzurisin, 1978). terraces; sharp break between wall and floor. Larger Rotational breaking by solar torques is another process likely to have occurred early in craters surrounded by well-defined continuous field of Mercurian history (Goldreich and Soter, 1966). With the formation of a solid lithosphere, stresses

seen under high solar-illumination angles to have bright (1977) has shown analytically that the expected pattern of fracturing includes linear strike-slip halos (albedo 0.20-0.27), rays, and areas of anomalously faults oriented roughly N. 60° W. and N. 60° E., and a younger set of thrust faults with east-west throw and rough north-south trends. Melosh and Dzurisin (1978) have pointed out the similarity Material of single or multiple rugged peaks near center of between this predicted tectonic pattern and that observed on Mercury, and they have proposed that the global system of lineaments and arcuate scarps, which is well developed in the Discovery Material of radial-rim facies of very sharp rimmed cratersquadrangle, formed in response to early, simultaneous planetary contraction and tidal dispinning. Anastomosing radial ridges grade outward to irregular The observable stratigraphic record in the Discovery quadrangle starts with formation of the hills and valleys that grade to individual satellitic craters intercrater plains, parts of which may have been coeval with the oldest observable craters. During (FDS 27382). Around craters < 70 km in diameter, this period, rates of volcanism were probably high as heat from core formation was being dissipated. individual ridges and valleys cannot be discerned, but If the crust was in a state of extension, there would have been easy pathways for large volumes of unit appears to mantle surrounding topography magma to reach the surface. The resulting plasticity of the crust probably caused large numbers Material of small, crisp, elongate, and coalescing craters of c₁ and c₂ craters to be destroyed by isostatic adjustment (Malin and Dzurisin, 1977; Schaber clustered around or radial to large c5 craters and others, 1977), so the present inventory of c₁ and c₂ craters may not be complete. Material of rims, walls, and floors of slightly subdued craters By c₃ time, the rate of volcanism had declined although the impact rate was still high. The and basins (FDS 166669)-Terraces and wall structure preservation of many secondaries 1 to 5 km across around c3 basins indicates that surface flows present; sharp break at base of wall; more superposed that would have obliterated them were highly restricted. However, some degradation of c3 basins craters than c₅ class. Larger craters and basins have occurred by isostatic adjustment. Most of the intermediate plains material formed at this time. flat floors, prominent, continuous rims, slightly modi-Smooth plains material appears to be largely coeval with c_4 craters and basins. The crust was fied terraces or other wall features, and well-preserved, under compression during c3 and c4 time, inasmuch as the compressional scarps and ridges postextensive satellitic crater fields; many filled with plains, date some c3 and c4 craters, and are cut by some c4 craters and by c5 craters. Formation of so central peaks and inner rings, if present, are not intermediate and smooth plains materials may have been abetted by the c3 and c4 crater- and basin-forming events that opened up temporary magma conduits. One of the latest large impacts Material of single or multiple rugged peaks near center of was the Caloris event, which occurred on the other side of the planet from the Discovery quad-

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rangle and which may have initiated formation of the hilly and lineated material within it.

small impacts, apparently at about the same rate as on the Moon.

Subsequent to formation of the smooth plains material, the Discovery quadrangle underwent

minor tectonic adjustments that formed scarps on plains within craters. The very smooth plains

unit was formed in some young craters. The only other activity was a steady rain of relatively

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SCARP-Line at base of slope; barb points downslope

FISSURE OR DEPRESSION OF STRUCTURAL ORIGIN-

Found only in hilly and lineated material (unit hl) ----- LINEAMENT-Trough, ridge, or scarp with low relative relief

CRATER RIM CREST, GREATLY SUBDUED OR AREA OF BRIGHT CRATER-RAY MATERIAL-Shown around some craters too small to map; shown primarily

in northwest quarter of map where illumination angle

allows discrimination AREA OF ANOMALOUSLY LOW ALBEDO-Shown only in northwest quarter of map where illumination angle

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