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GEOLOGIC INVESTIGATION OF MERCURY DATA AND THE SUBSEQUENT MAPPING AND EXPLANATION OF THE QUADRANGLE AREA H-12

FINAL REPORT

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Submitted by:

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ABSTRACT

Scarps and ridges of apparent non-impact origin mapped in the H-12 region have distinctly non-random patterns of distribution and orientation. These patterns cannot be simply related to selective enhancement of visibility by lighting conditions, global stresses of spin down or interior cooling, or local uplifts or subsidences. It is suggested that the origin of these structures (if part of a radial pattern) may lie outside the region of Mercury photographed (to the northwest of H-12) or the scarps and ridges may have formed by reactivation of faults or joints bounding pre-existing crustal blocks. Thus, the trends of the presently observed ridges and scarps may have little to do with the global stresses which created them.

This report is an account of the first year of work by one co-author of a geologic map to cover the H-12 and H-13 quadrangle regions of Mercury photographed by the Mariner 10 spacecraft (20°S to 70°S and 90°W to 195°W, see Figure 1). Because of the absence of obvious contacts between surface material units (other than crater materials) the first geologic mapping task undertaken was the compilation of a structural/topographic map of features apparently unrelated to impact cratering. It was hoped that the morphologies, trends and transectional relationships of such surface features would help define tectonic or volcanic episodes in Mercurian history.

Data

The H12-13 region (Fig. 1) was photographed at moderate resolution (1 to 2 km features can be distinguished) during the second flyby of Mercury by Mariner 10. The northern margins of this region were also photographed at similar or lower resolution during the first flyby. Differences in viewing geometry between the two flybys and among pictures acquired during the second flyby provide stereo imaging of almost the entire region being mapped.

Features other than impact craters have now been mapped from 107 stereo image pairs covering most of the H-12 - 13 region (Figure 2). In the remaining areas monoscopic imaging has been examined for prominent features. By far the most abundant features recognized are scarps and ridges. These features have been identified as to orientation, length, and location on two separate maps (Figs. 3 and 4).

Scarps

Rose diagrams of scarp length versus orientation have been constructed for a grid of areas covering the H-12 Quadrangle (Fig. 5). These show patterns of organization among surface features which cannot be explained simply as effects of variable lighting conditions preferentially enhancing the visibility of slopes facing toward or away from the sun. The subsolar point during the Mariner 10 flybys was located about 95°W and 0°N. The terminator in the region studied here lay approximately along the 185°W meridian. The grid of rose diagrams covering the area of H-12 would thus be expected to show the effect of lighting enhancement of topography with strong N-S trends in the western third of the quadrangle (150-180°W), strong E-W trends in the eastern third (90-120°W), and strong NW-SE trends in the central third (120-150°W). To a limited degree these trends seem to be represented by enhanced total scarp lengths for scarps facing both toward and away from the sun. In the area 150-180°W and 20-30°S, two lobes of the rose diagram trend close to N-S. Also in the central region of H-12 between 50° and 70°S both NW-SE trends dominate the recognized scarps. In other areas, a single rose diagram lobe, corresponding to scarps facing toward (as 150-180°W, 40-50°S) or away from the sun only (as 120-150°W, 20-30°S), is strongly enhanced. Such anomalies in rose diagram symmetry might be related to digital image enhancement algorithms which favored either highlighted or shadowed scarps under different ranges of lighting conditions, but additional strong scarp trends apparently unrelated to sun position also appear in the data. West-facing scarps dominate the area 120-150°W, 30-40°S and scarps facing SW are in great abundance 150-180°W, 20-30°S.

The strongest trends of scarps not related to lighting show up clearly in the fourth column of rose diagrams (Fig. 5) summing all longitudes in four latitude ranges. From 20-30°S SW facing scarps are prominent. From 30-40°S, W and NE facing scarps are most abundant. From 40-50°S, SW and NE facing scarps are both enhanced. E and W facing scarps are enhanced to a lesser degree. In the latitude range 50 to 70°S, NE, SW, and SE facing scarps are enhanced. Aside from the variations with latitude, trends of scarps vary greatly with longitude across the H-12 region. The map of Fig. 3 shows the occurrence of all scarps. Using the rose diagrams to pick out prominent local features, a generalized map showing scarp complexes has been compiled (Fig. 6). Except to the northeast, where adverse lighting conditions and gaps in the stereo data (Fig. 2) made their recognition difficult, nineteen scarp complexes, each hundreds of kilometers long, are well distributed across the H-12 -13 region. The scarp complexes can be divided into three classes:

1. N-S trending (8)
2. NW-SE trending (8)
3. Lobate (3)

N-S trending scarp complexes are most prominent above 40°S. With only two exceptions, they face westward. The two east facing scarp complexes lie south of 45°S.

NW-SE trending scarp complexes are more evenly distributed in latitude and longitude and do not show a strong tendency to face one direction.

Three generally lobate scarp complexes occur in the H-12 -13 region. The previously recognized Hero Scarp (Strom, et al., 1975; Dzurisin, 1977) centered about 58°S, 172°W, is part of a complex about 550 km long overall. It arcs around from east, and south-facing, to west and southwest facing.

A second lobate scarp complex, about 520 km long, is centered about 45°S, 137°W. From north to south scarps change from NE to E facing.

The third lobate scarp complex is about 500 km long and centered 60°S, 100°W. From east to west the scarp orientations change from SE to S facing.

The three large lobate scarp complexes all lie south of 40°S, otherwise no patterns to their distributions or orientations are seen.

Taken together the scarps of the H-12 -13 region are distributed and oriented in a highly non-random fashion. NE-SW and E-W trends are absent from the linear scarp complexes. North of 40°S west facing N-S trending scarps are common and NW-SE trending linear scarps also occur. Below 40°S lobate scarps and NW-SE trending linear scarps are the dominant patterns.

Ridges

Far fewer ridges than scarps have been recognized in the H-12 -13 region (Fig. 4). In many cases ridges are closely associated with groups of scarps and trend parallel to them (as at Hero Scarp 58°S, 171°W or near 100°W, 60°S). In a few cases a feature as resolved, could have been represented equally well as a pair of oppositely facing scarps or a ridge, so an arbitrary choice was made as to map symbol.

In some cases ridges seem to represent large scale structures comparable to scarp complexes or extend structures recognized from scarps (Fig. 6). Near 30°S, 100°W, a pair of large ridges trending NW-SE extend over a distance of about 200 km.

In the region 125-130°W, 35-45°S two N-S trending ridges seem to fill in a structural gap between two N to NW trending scarp complexes. Most of the other prominent ridges trend parallel to N-S and NW-SE trending scarps in the north central part of the H-12 -13 region.

Rose diagrams (Fig. 5) and the map of scarp locations (Fig. 4) show less suggestion of influence by lighting conditions than was the case for scarps. No tendencies to cluster near the terminator or to align perpendicular to the sun azimuth are seen. The only strong pattern is a tendency to trend parallel to the most prominent groups of scarps, suggesting a common structural origin for both types of features.

Other Features

Other features possibly formed, at least in part, by non-impact processes, have also been recognized. These include:

1. Modified craters - apparent impact craters either a) cut off or offset across scarps or b) highly modified by mantling (Fig. 7).
2. Mountains - more or less approaching cylindrical symmetry
3. Closed depressions - irregular in plan
4. Lineations - of uncertain topography
5. Troughs - highly elongate depressions

A preliminary map of the distribution of these features is shown in Fig. 7. Except for troughs these features are more difficult to detect and map than are scarps and ridges; a definitive study will require closer examination of a complete set of stereo data and some compilation of topographic maps.

Craters modified along scarps (a, Fig. 7) may be visible only on one side of the scarp (either high or low) or may be offset vertically or horizontally. Another class of highly modified crater (b, Fig. 7) resembles lunar "ghost craters" on maria; only the crater rim is preserved as a broad low ridge rising above a generally smooth plain. Mantling by impact ejecta or volcanics seems the most probable origin of these features.

A class of Mercurian features whose distribution has not previously been mapped is isolated mountains of more or less symmetric form. Because their slopes are generally much lower than those of crater walls, and their surface textures are identical to the intercrater plains (saturated with small craters) these mountains are nearly undetectable from single photographs. They are easily seen stereoscopically, however. Two mountains are associated with the east end of the Hero Scarp complex and a group of four is located near the east boundary of H-12, 30 to 50°S.

Other features of possible non-impact origin are irregular closed depressions, lineations, and troughs. No strong patterns are seen to their orientations or locations.

Discussion

The scarps and ridges of the H-12 - 13 region photographed by Mariner 10 are not organized into patterns which lend themselves to easy explanation as the result of a coherent local or global tectonic pattern. In the H-11 region and adjacent areas to the north, Dzurisin (1977) found patterns which he related to global stresses of planetary spin down and contraction. (Melosh, 1977). No similar patterns have been detected in the region studied here although it covers much of the same latitude band and lies immediately west of H-11.

The strong non-random patterns to scarp and ridge orientations and distributions suggest possible larger hemispheric or global tectonic patterns which could be studied outside the limits of this mapping project. For instance there is an extremely strong NW-SE structural grain in the H-12 - 13 region. Continuation of these trends to the SE should be investigated, as well as the possibility that these may be part of a system of radial structures extending from a feature on the unphotographed hemisphere of Mercury.

Taken wholly within the context of the H-12 -13 region, the patterns of scarps and ridges fail to define structural basins or uplifts which might have served as loci of stresses. An irregular pattern of vertical and horizontal adjustment along the margins of crustal blocks is suggested. Perhaps this came about as the result of the crust being broken up by entirely different stresses (perhaps by impact events) than those which caused the adjustments now expressed at the surface as scarps and ridges.

The later stresses may have been due to planetary spin-down or cooling. Though the morphology of individual scarps and ridges may favor an origin in a planet-wide compressional tectonic regime (Strom, et al., 1975; Dzurisin, 1977) trends may be fossil, deriving from earlier stresses.

References

Dzurisin, D., 1977, Scarps, Ridges, Troughs, and other Lineaments on Mercury: Ph.D. Thesis, California Institute of Technology.

Melosh, H.J., 1977, Global Tectonics of a Despun Planet: in press, J. Geophysical Res.

Strom, R.G., Trask, N.J., and Guest, J.E., 1975, Tectonism and Volcanism on Mercury: J. Geophysical Res., 80, 2478-2507.

Figures

1. Shaded relief map of the H-12 - 13 region studied. Compiled from Mariner 10 photography by the U.S. Geological Survey, Flagstaff, Arizona.
2. Blacked out areas had no usable stereo images available for this study.
3. Distribution of scarps; symbol line lies along base, barb points downdip.
4. Distribution of ridges.
5. Rose diagrams of length vs. orientation for scarps and ridges within subdivisions of the H-12 region.
6. Generalized map of groups of scarps and prominent ridges in the H-12 -13 region
7. Map of apparent non-impact features other than scarps and ridges within the H-12 -13 region.

FIGURE 1

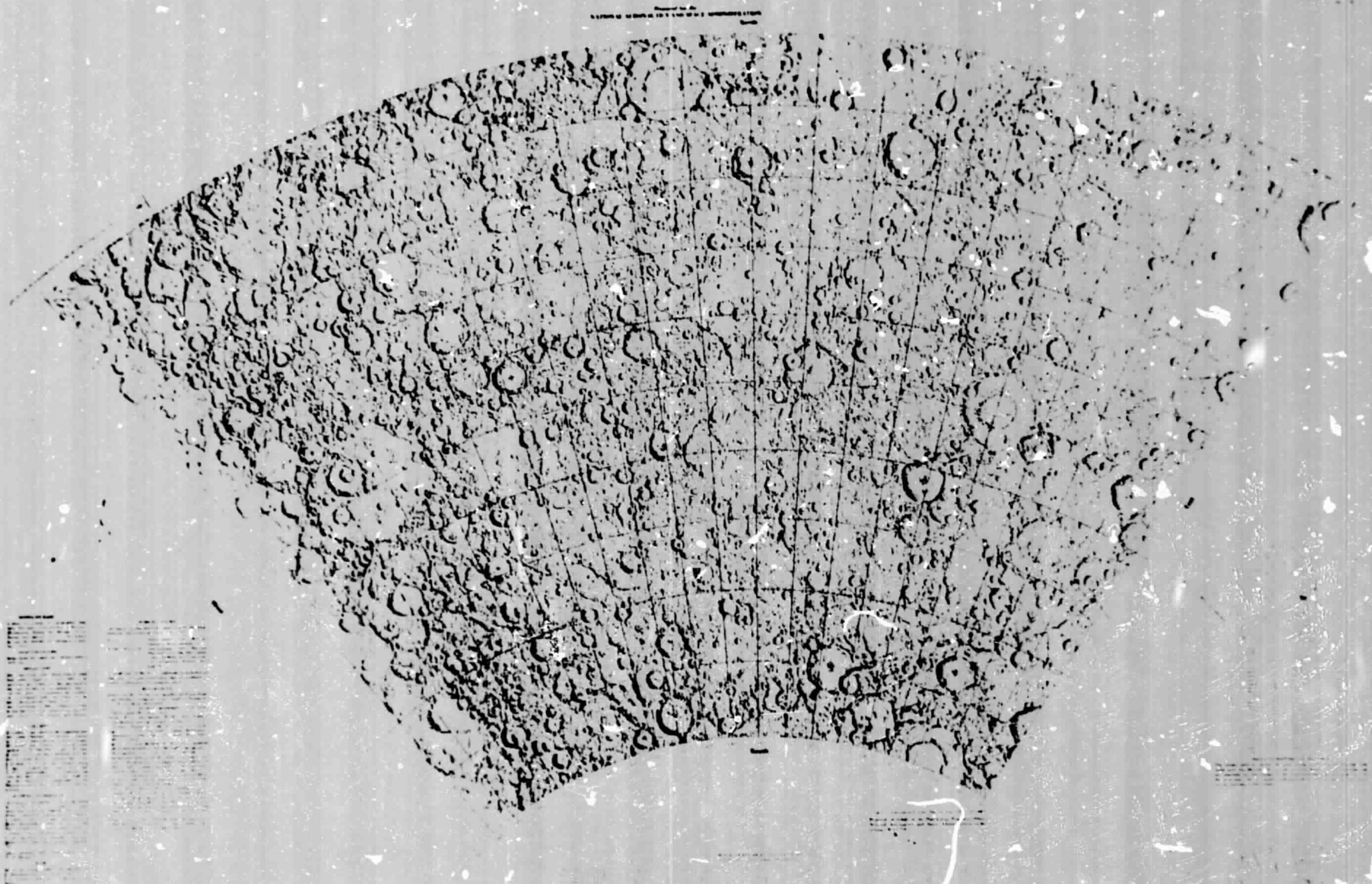

FIGURE 2

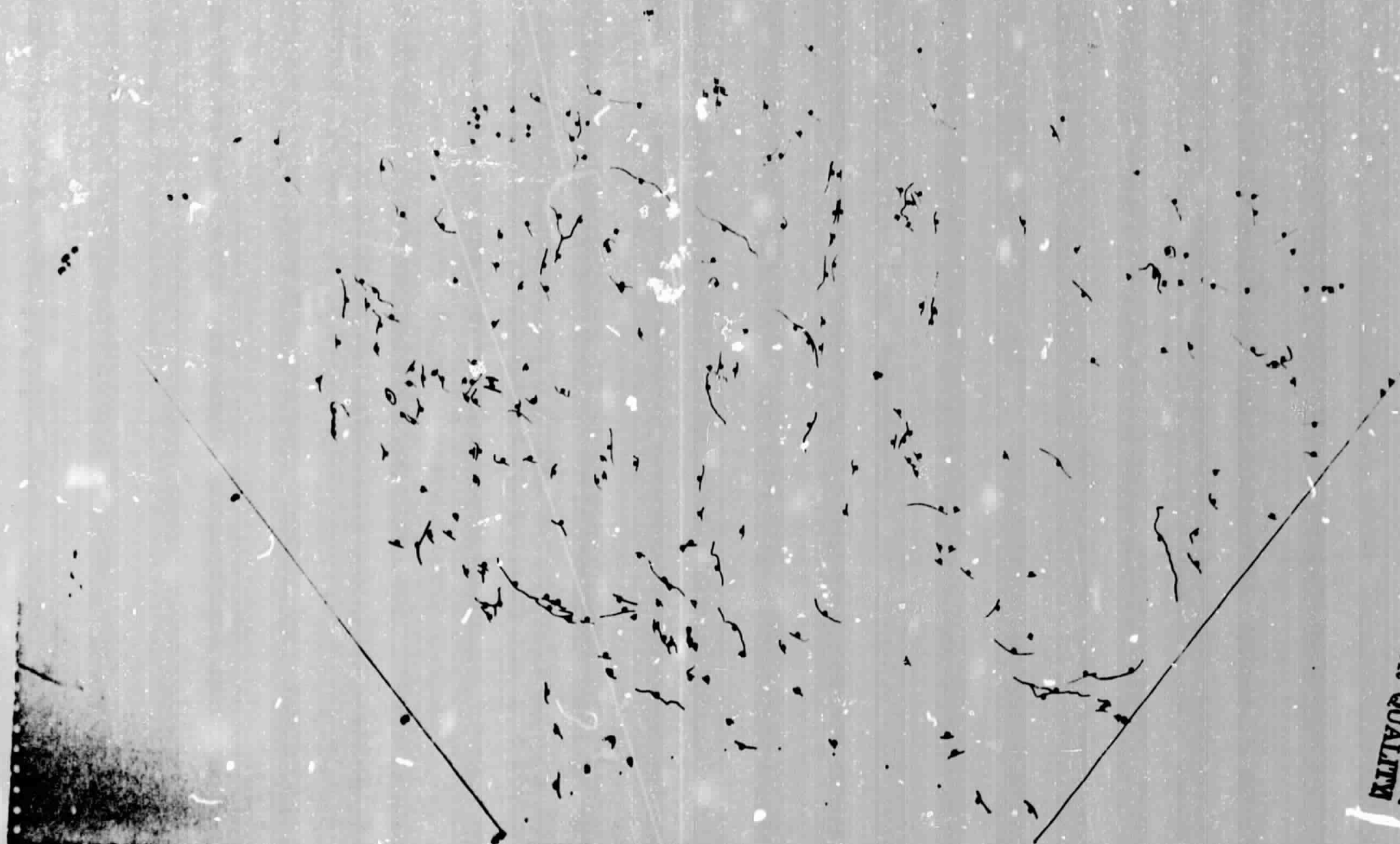

FIGURE 3

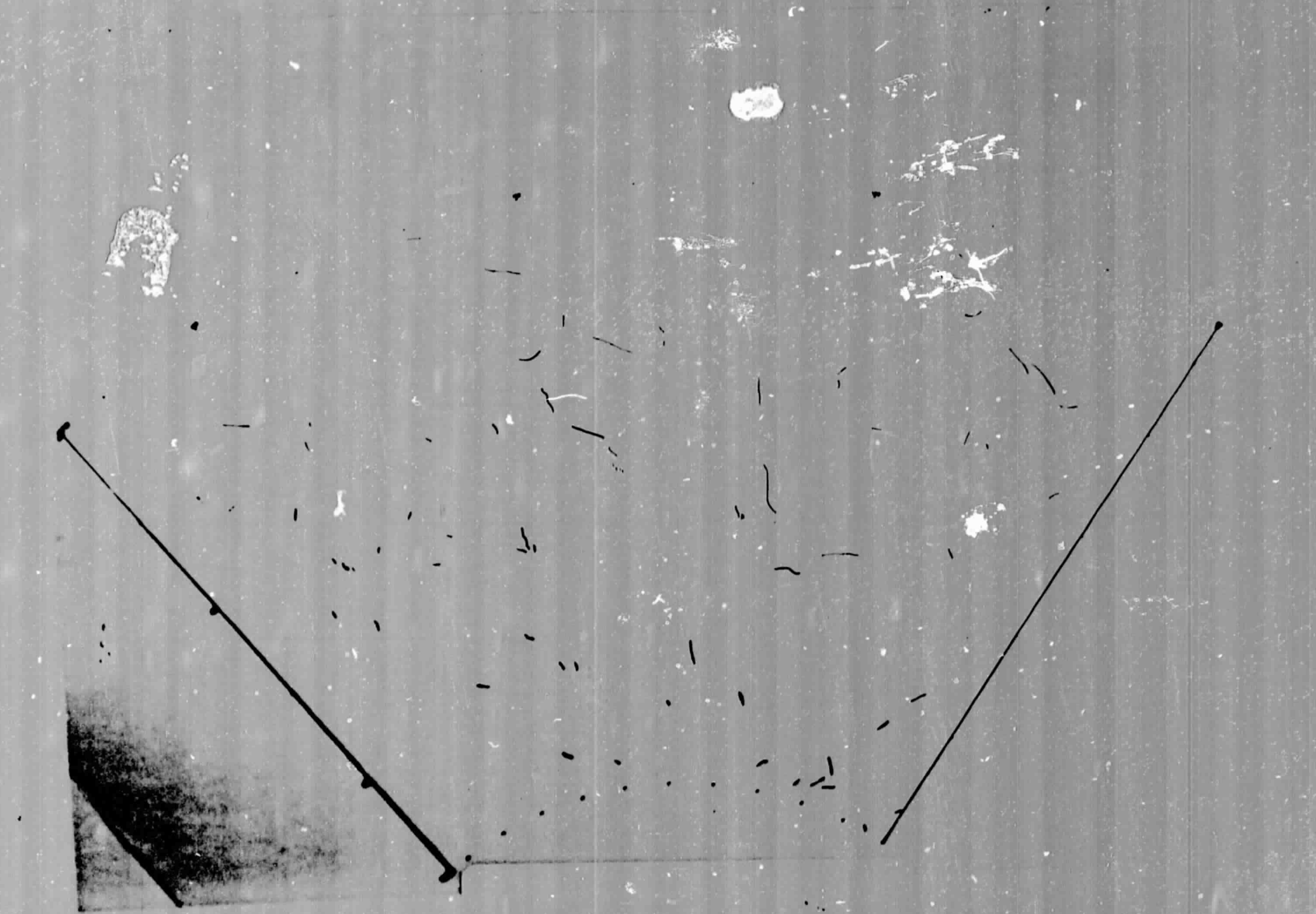

FIGURE 4

ORIENTATIONS OF SCARPS AND RIDGES OF APPARENT NON IMPACT ORIGIN.MERCURY H12 QUADRANGLE

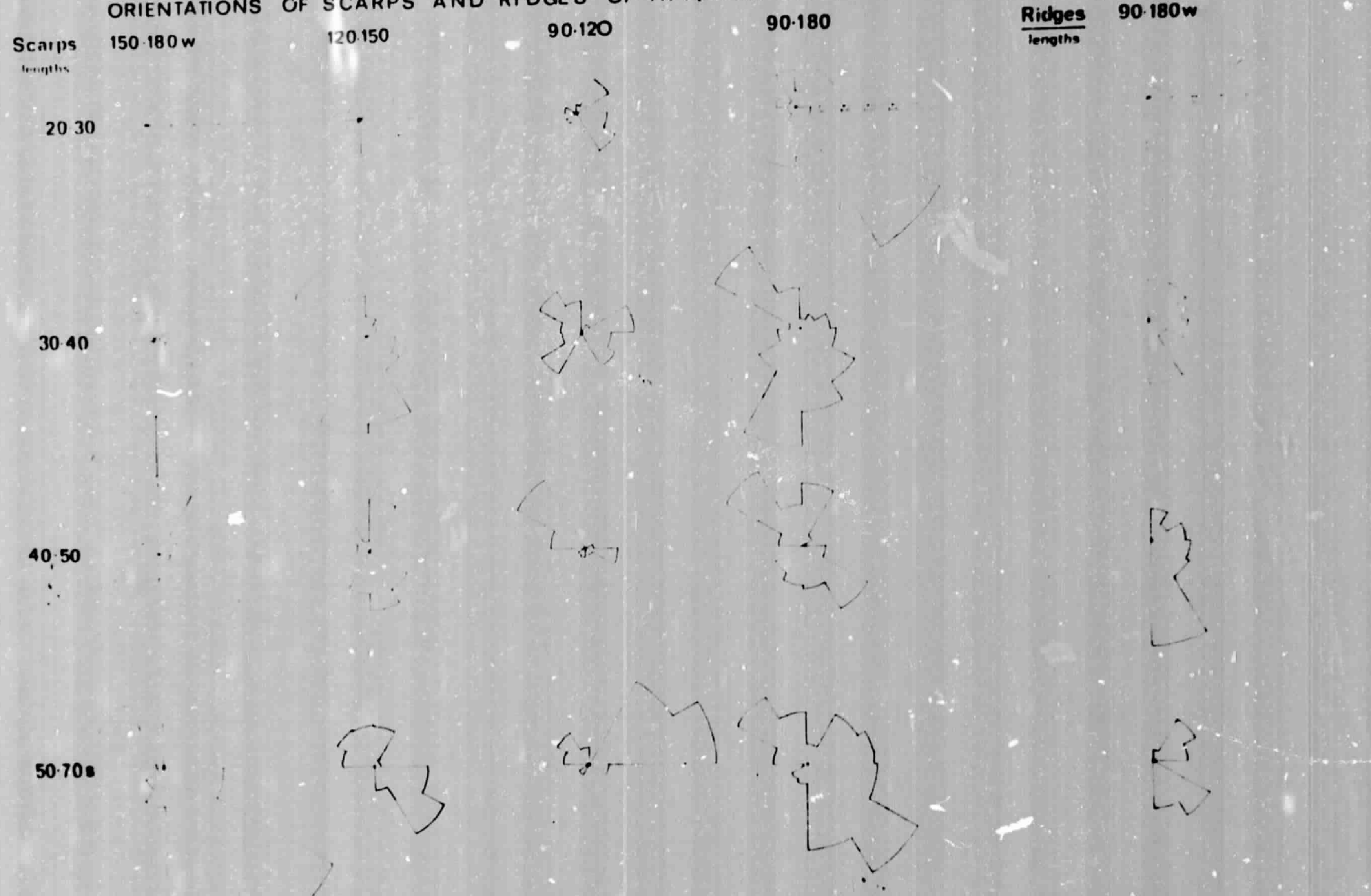

FIGURE 5

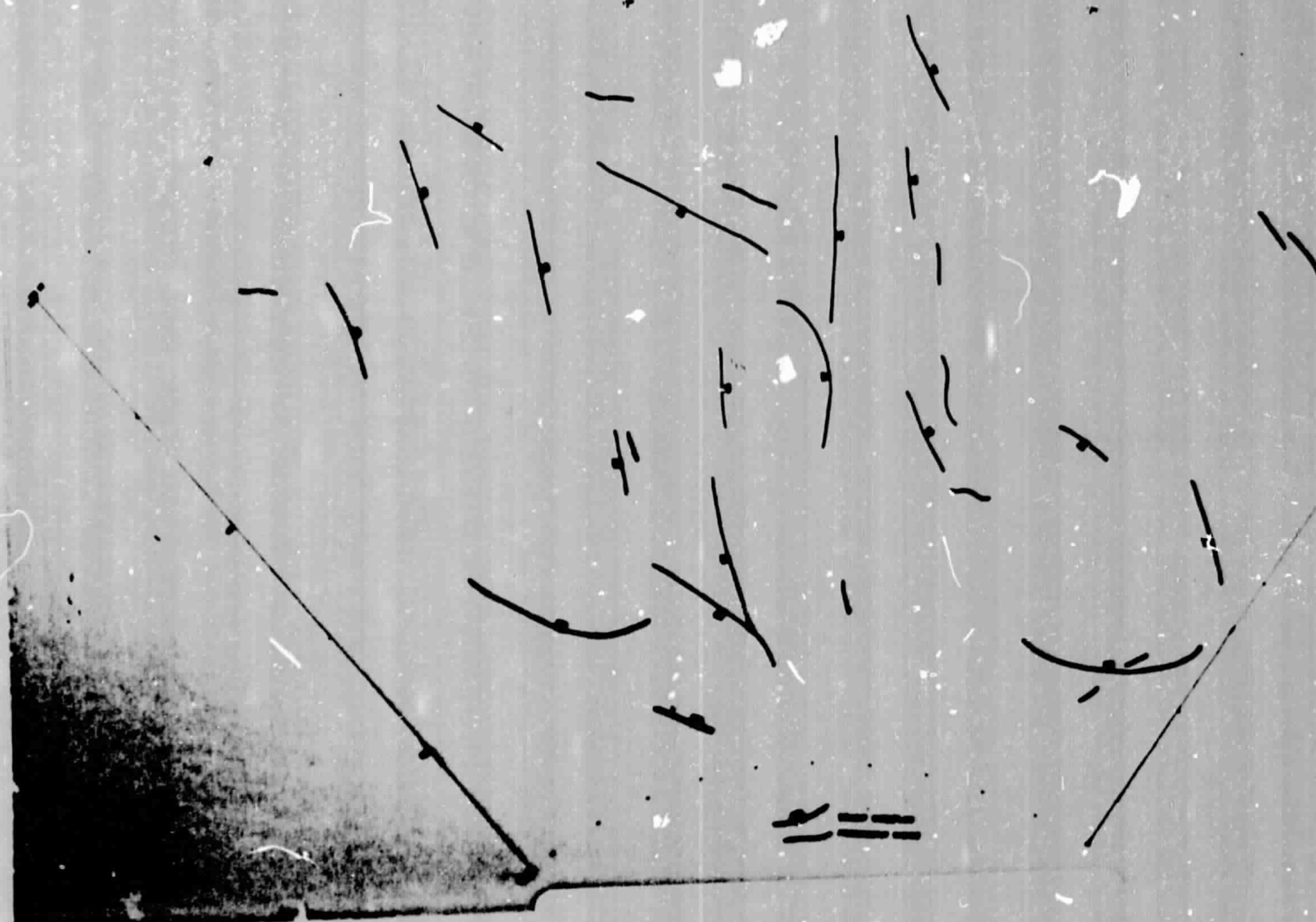

FIGURE 6

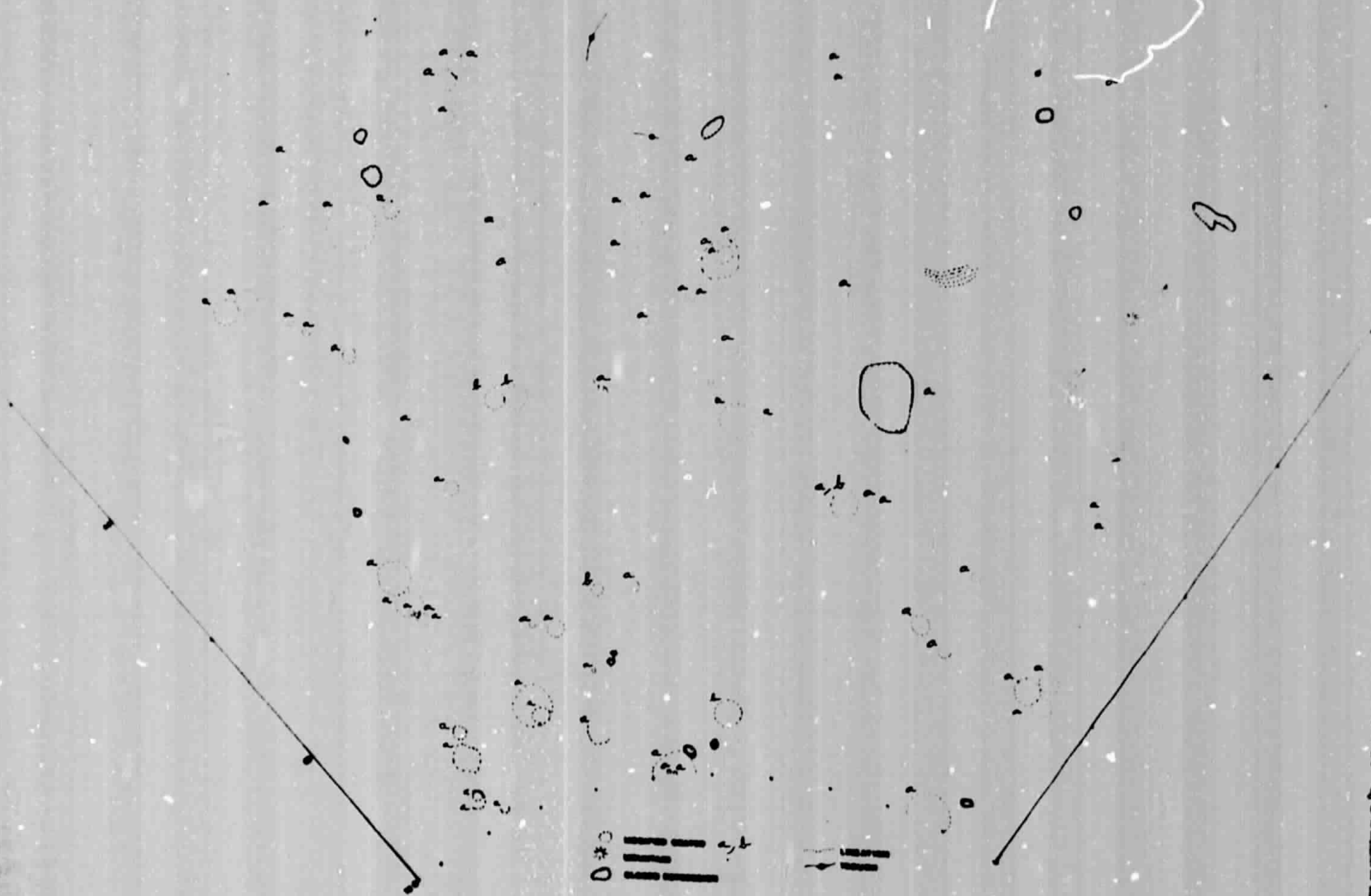

FIGURE 7