3 12885

1.0 2.8 3.2 2.2 3.6 4.0 2.0 1.1 1.8 1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS – 1963

Directions of Strong Winds on Mars Inferred From Mariner 6 and 7 Photography

by

Alan D. Howard

N73-12885

(NASA-CR-129520) DIRECTIONS OF STRONG WINDS ON MARS INFERRED A.D. Howard (Virginia Univ.) 5 May 1972 20 p CSCL 03B

Unclas
G3/30 16136

Department of Environmental Sciences
University of Virginia
Charlottesville, Virginia 22903
May 5, 1972

ABSTRACT

Asymmetrical crater shadings and diffuse light and dark streaks visible on the photography returned by the 1969 Mars flyby of Mariners 6 and 7 are probably eolian in origin. Wind directions inferred from mapping of these features parallel motions of observed global dust storms or relate to expected patterns of topographic funneling of winds.

INTRODUCTION

Albedo features on Mars have been reported as partially eolian in origin by several authors (Rea, 1964; Gifford, 1964b; Sagan and others, 1971; Sagan and Pollack, 1967; Cutts and others, 1971). Evidence confirming this includes determinations of the size and composition of the surface materials (Pollack and Sagan, 1969; Morrison and others, 1969), observations of yellow clouds of silicate dust (Gifford, 1964a; Slipher, 1962; Hanel and others, 1972; Kirby and Robinson, 1971; Capen, 1971), the superficial nature of the albedo markings (Cutts and others, 1971), and estimates of wind velocities sufficient to move granular materials (Gierash and Sagan, 1971). If eolian redistribution and sorting is common on Mars, the albedo features should be related to the atmospheric circulation, because the size of granular materials affects their albedo (Pollack and Sagan, 1969). Dark areas are described by Sagan and Pollack (1967) and Sagan and others (1971) as slopes or uplands swept clear of fine detritus, and light areas as lowlands or flats of deposition. Eolian influence on albedo must extend to smaller erosional and depositional features, some of which might indicate the mean directions of the high velocity winds carrying detritus. An examination of Mariner 6 and 7 photography has revealed two types of oriented features which may be eolian:

1. <u>Light and dark streaks</u>: At the resolution of Mariner 6 and 7 A-Frame imagery, which provide the broadest high-resolution coverage, only surface features larger than about 3 km in their smallest dimension are visible. On Earth at this scale individual dunes would not be distinguishable, but sand sheets, compound dunal forms, large deflation pavements, and some eolian erosional features would be discerned. Wind directions are revealed in large eolian features by an elongation parallel to the wind. Transverse and oblique elongations of pavements and sand sheets occur less frequently,

especially where they are controlled by topography or by the disposition of the source area for the sediment. Most of the wide angle television frames reveal light and dark streaks; however, some of these are artifacts from the imaging system (discussed below), while others are topographic features formed by tectonism or by non-eolian exogenetic processes. Sharp-edged or abruptly-bending linear features on Mariner photographs generally result from non-eolian processes; such features, including rills, scarps, presumed fracture traces, crater rims, and the south polar ridges (Sharp and others, 1971a, p. 364) are not mapped. However, an eolian origin is suspected for the broad, diffuse, and gently-curving streaks mapped in Figures 1 and 2. Linear streaks on the martian south polar cap are thought to be eolian in origin (Sharp and others, 1971a).

2. Directional features: The floors of some craters photographed by Mariners 6 and 7 exhibit a crescent- or half-moon shaped area of light albedo bordering the crater walls, which contrast with a patch of dark albedo comprising the opposite side of the crater floor (Fig. 3). Cutts and others (1971, p. 354-356) conclude that the light area is an infilling of transported material, presumably by eolian processes. Terrestrial examples of craters partially filled by sand support this interpretation (Smith, 1971). Because of the asymmetry of the albedo markings, the average direction of the wind filling the crater is presumed to be given by an arrow bisecting the light and dark areas and pointing from light to dark (Figs. 1-3). In addition to the crater fillings, a few light and dark streaks initiate at distinguishable topographic features, such as at the base of escarpments in the "chaotic terrain" (Sharp and others, 1971b, p. 331), or at tails extending from craters. These streaks may be "shadow dunes" or wind-scoured areas controlled by wind funneling or turbulence behind the topographic feature. Such streaks are also indicated by arrows.

MAPPING PROCEDURES

Because of the subjectivity involved in the mapping of presumed eolian features, the author and Leon LeVan independently constructed maps from the Mariner imagery. The two versions agree very well on the major linear streaks and conspicuous crater shadings while differing on the interpretation of lesser features; Figures 1 and 2 are an edited composite of these maps. Orthographic projections of both the maximum discrimination (high-pass filter) and photometrically corrected versions of the imagery were used in mapping. Latitude and longitude of mapped features are based upon the 1969 control net for Mars (Davies and Berg, 1971).

Because of inherent limitations of the television system used on the Mariner spacecrafts, features appear on the photographs which are artifacts from the imaging system (Masursky and others, 1972, p. 297-298). Several types of artifacts occur. Most common are scan-line defects; most affect only one line, but their effect is widened by enhancement processes applied to the pictures (Rindfleisch and others, 1971). All streaks nearly parallel to the scan lines were scrutinized as possible artifacts. Coherent noise produces lines at various angles to the scan lines; because these are repetitive, their effects are easily detected. False features of low contrast are also introduced by residual images from previous frames and from inhomogeneities in the vidicon system. These false images are most prominant and most difficult to distinguish from surface features when superimposed on low contrast scenes near the evening terminator or in nearly featureless terrains such as the floor of Hellas (Fig. 2). Such false images are best detected by comparison with preceding pictures.

Some of the streaks mapped near the evening terminator in the eastern portion of Hellas and near the South Pole (Fig. 2) may be broad swales and ridges transverse to the direction of illumination accentuated by the low sun angle rather than intrinsic albedo differences produced by eolian transport. Because of the gentle slopes prevailing on Mars (Pettengill and others, 1971; Rogers and others, 1970), only angles of illumination less than 10-15 degrees are likely to reveal broad streaks attributable to topography. Steeper slopes, such as crater rims, polar ridges, and escarpments in the chaotic terrain, show the effects of uneven illumination at higher sun angles, but these are usually distinguishable by their narrowness, texture, and sharp boundaries.

INTERPRETATION

The hypothesis of major eolian activity on Mars would be greatly enhanced if a consistent pattern of linear and directional features were to emerge from global mapping, particularly if these relate in a reasonable way to expected directions of strong winds. Such a case exists for Terrestrial eolian features; their orientations relate reasonably to observed winds (Brookfield, 1970; Warren, 1970; Landsberg, 1956; Rudberg, 1968). Although only a small portion of Mars was photographed by Mariners 6 and 7 with sufficient ground resolution for this mapping project, consistency is shown by a general parallelism between adjacent linear and directional features. Some of the scattering of directions may result from mapping of false images, from control of albedo by structure, topography, or bedrock outcroppings, and possibly from superposition of deposition or erosion by winds from different directions. The directional features, which are mostly crater fillings, are most consistent in their parallelism, suggesting that they indicate wind direction.

In the equatorial region near Meridiani Sinus (Fig. 1) the inferred wind direction is nearly north-to-south, although there is the suggestion of a counterclockwise rotation from south-southwest north of the equator to south-southeast below it. North-south winds might result from topographic funneling of winds (Sagan and others, 1971). Meridiani Sinus lies on the eastern flank of a broad regional valley striking north-south (Pettengill and others, 1971; Rogers and others, 1970). Few yellow clouds have been observed in the Meridiani Sinus area, but repeated north-to-south movement has been noted in the Isidis Regio-Libya region, another north-south regional valley (Sagan and others, 1971). During the 1956 global dust storm, a yellow cloud moved northwestward between Margarifiter Sinus and Mare Eurethaem towards Aurore Sinus (Sagan and others, 1971, p. 268-269; Dollfus, 1965). The linear streaks in this area parallel that trend (Fig. 1).

At latitudes below 30 S (Fig. 2) the dominant wind direction appears to be from the southeast. At far southern latitudes the mapped features strike east-west, but they are more north-south at lower latitudes. These relationships would be consistent with the coriolis effect on winds moving northward from the polar cap, driven by the strong latitudinal surface temperature gradient adjacent to the polar cap during the martian spring and summer (Neugebauer and others, 1971). This season produces global martian dust storms, especially near perihelion; the large dust storms of 1956, 1969, and 1971 originated in the Noachis-Hellespontis area (Fig. 2) and moved in a tight spiral to the west, extending fingers northward towards the equator (Kirby and Robinson, 1971; Capan, 1971; Gierash and Sagan, 1971; Dollfus, 1965). This pattern contrasts with the dominant eastward movement of mean winds and cyclone tracks at similar latitudes in the southern hemisphere on Earth (Weyant, 1967).

The nature of the streaks and crater shadings mapped here is uncertain; if they are indeed eolian, the light streaks may be thick sand bodies which require long periods of consistent winds to deposit, or they may be thin, mobile sheets which shift rapidly during successive dust storms. Comparison of the present maps with similar global mapping of wind-produced features revealed on Mariner 9 photography taken subsequent to the 1971 dust storm may help determine their permanence. Streaks mapped on the south polar cap are a special case; they may be areas of uneven CO_2 ice deposition or sublimation controlled by wind movement, they may be differences in the albedo of underlying material visible though the thin cap, or they may be produced by subtle topographic or sun-angle control of CO_2 deposition or sublimation (Sharp and others, 1971a). In all but the second case the polar cap features would be ephemeral. The streaks mapped in Hellas may also be ephemeral; some authors suspect that a local dust storm obscured the surface during the flyby of Mariner 7 (Sharp and others, 1971b, p. 336; Sagan and others, 1971, p. 266).

ACKNOWLEDGEMENTS

I thank L. LeVan and E. Gilmore for technical assistance and R. Dolan for critical review of the manuscript. The work was conducted under NASA contract NGR 47-005-142.

REFERENCES CITED

Brookfield, M., 1970, Dune trends and wind regime in Central Australia: Zeit. für Geormorph., Suppl. 10, p. 121-153.

Capen, C.F., 1971, Martian yellow clouds -- past and future: Sky and Telescope, v. 41, p. 117-120.

Cutts, J.A., Soderblom, Sharp, R.P., Smith, B.A., and Murray, B.C., 1971, Surface of Mars -- light and dark markings: Jour. Geophys. Research, v. 76, p. 343-356.

Davies, M.E., and Berg, R.A., 1971: A Preliminary control net of Mars: Jour. Geophys. Research, v. 76, p. 373-393.

Dollfus, A., 1965, Etudé de la planete Mars de 1954 a 1958: Annals Astrophysique, v. 28, p. 722-747.

Gierash, P., and Sagan, C., 1971, Preliminary assessment of martian wind regime: Icarus, v. 15, p. 312-318.

Gifford, F.A., Jr., 1964a, Study of martian yellow clouds that display movement: Monthly Weather Review, v. 92, p. 435-440.

----- 1964b, Martian canals according to a purely aeolian hypothesis: Icarus v. 3, p. 130-135.

Hanel, R.A., Conrath, B.J., Hovis, W.A., Kunde, V.G., Lowman, P.D., Pearl, J.C., Prabhakara, C., Schlachman, B., and Levin, G.V., 1972, Infrared spectroscopy experiment on the Mariner 9 mission: preliminary results: Science, v. 175, p. 305-308.

Kirby, T.B., and Robinson, J.C., 1971, Dust storm observations from New Mexico: Sky and Telescope, v. 42, p. 264-265.

Landsberg, S.Y, 1956, Orientation of dunes in Britain and Denmark in relation to wind: Geog. Jour., v. 122, p. 176-189.

Masursky, H., and others, 1972, Mariner 9 television reconnaissance of Mars and its satellites: preliminary results: Science, v. 175, p. 294-305.

Morrison, D., Sagan, C., Pollack, J. B., 1969, Martian temperatures and thermal properties: Icarus, v. 11, p. 36-45.

Neugebauer, G., Münch, G., Kieffer, H., Chase, S. C., Jr., and Miner, E., 1971, Mariner 1969 infrared radiometer results: temperatures and thermal properties of the martian surface: Astronomical Jour., v. 76, p. 719-728.

Pettengill, G. H., Rogers, A. E. E., and Shapiro, I.I., 1971, Martian craters and a scarp as seen by radar: Science, v. 174, p. 1321-1324.

Pollack, J. B., and Sagan, C., 1969, Analysis of martian photometry and polarimetry, Space Science Reviews, v. 9, p. 243-299.

Rea, D. G., 1964, Darkening wave on Mars: Nature, v. 201, p. 1014-1015.

Rindfleisch, T. C., Dunne, J. A., Frieden, H. J., Stromberg, W. D., and R. M. Ruiz, 1971, Digital processing of the Mariner 6 and 7 pictures: Jour. Geophys. Research, v. 76, p. 394-417.

Rogers, A. E. E., Ash, M. E., Counselman, C. C., Shapiro, I. I., and Pettengill, G. H., 1970, Radar measurements of the surface topography and roughness of Mars: Radio Science, v. 5, p. 465-473.

Rudberg, S., 1968, Wind erosion -- preparation of maps showing the direction of eroding winds: Biul. Perygl., v. 17, p. 181-193.

Sagan, C., Veverka, J., and Gierasch, P., 1971, Observational consequences of martian wind regimes: Icarus, v. 15, p. 253-278.

Sagan, C. and Pollack, J. B., 1967, Windblown dust model of martian surface features and seasonal changes: Smithsonian Astrophysical Observatory Special Report 255, 43 p.

Sharp, R. P., Murray, B. C., Leighton, R. B., Soderblom, L. A., and Cutts, J. A., 1971a, Surface of Mars 4. south polar cap: Jour. Geophys. Research, v. 76, p. 357-372.

Sharp, R. P., Soderblom, L. A., Murray, B. C., and Cutts, J. A., 1971b, Surface of Mars 2. uncratered terrains: Jour. Geophys. Research, v. 76, p. 331-342.

Slipher, E. C., 1962, The photographic story of Mars: Cambridge, Mass., Sky Publ. Co., 168 p.

Smith, H. T. U., 1971, The question of eolian action on Mars: Geol. Soc. America, Abs. with Programs, v. 3, p. 710.

Warren, A., 1970, Dune trends and their implications in the central Sudan: Zeit. für Geomorph., Suppl. 10, p. 154-180.

Weyant, W. S., 1967, The Antarctic atmosphere: climatology of the surface environment: Am. Geogr. Soc., Antarctic Map Folio Series, Folio 8.

Figure 1. Wind directions in the equatorial region of Mars near its prime meridian interpreted from oriented surface features of probable eolian origin. The dark region of Meridiani Sinus is the westward extension of Sinus Sabaeus near 0°W longitude and 5°S latitude.

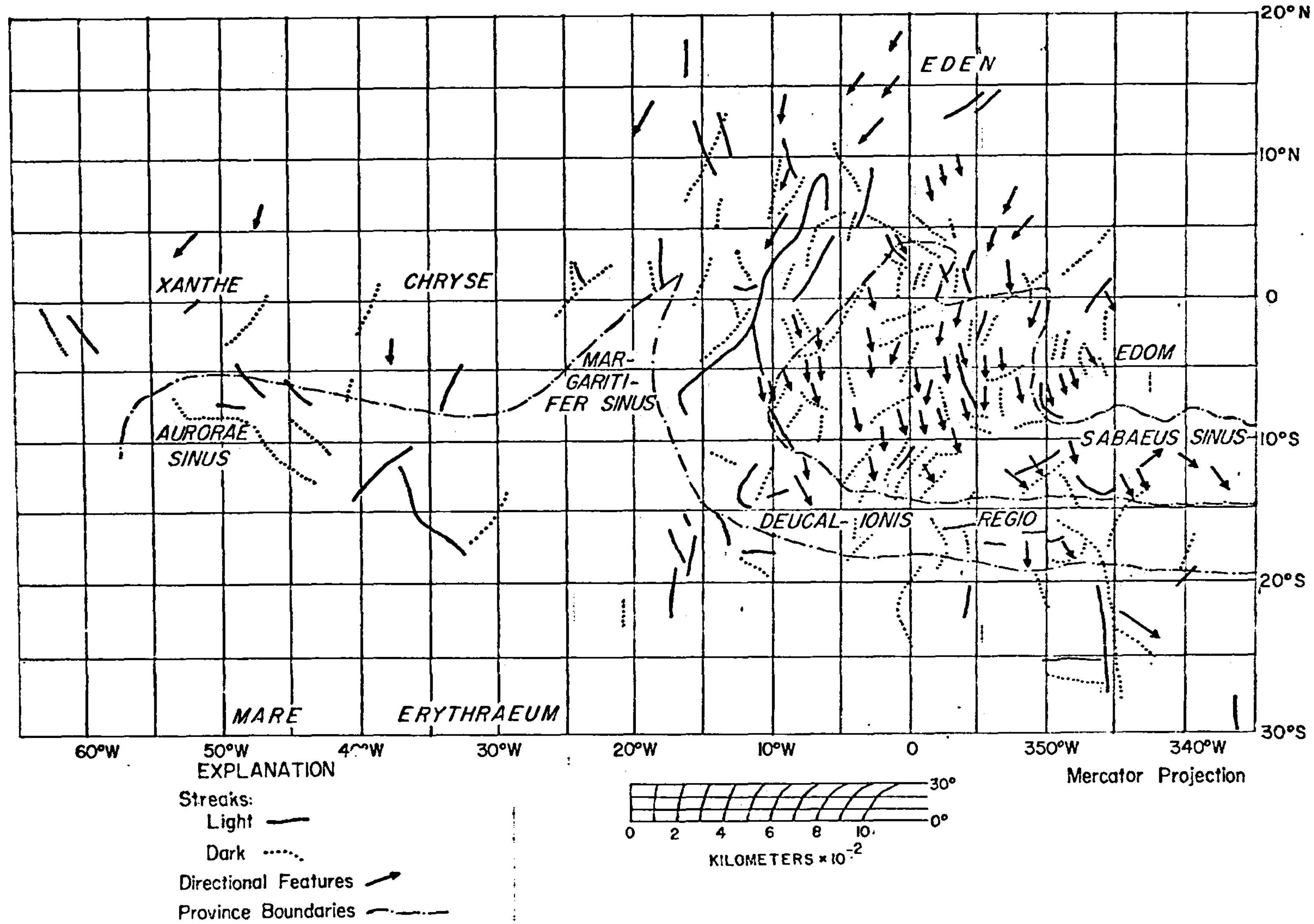
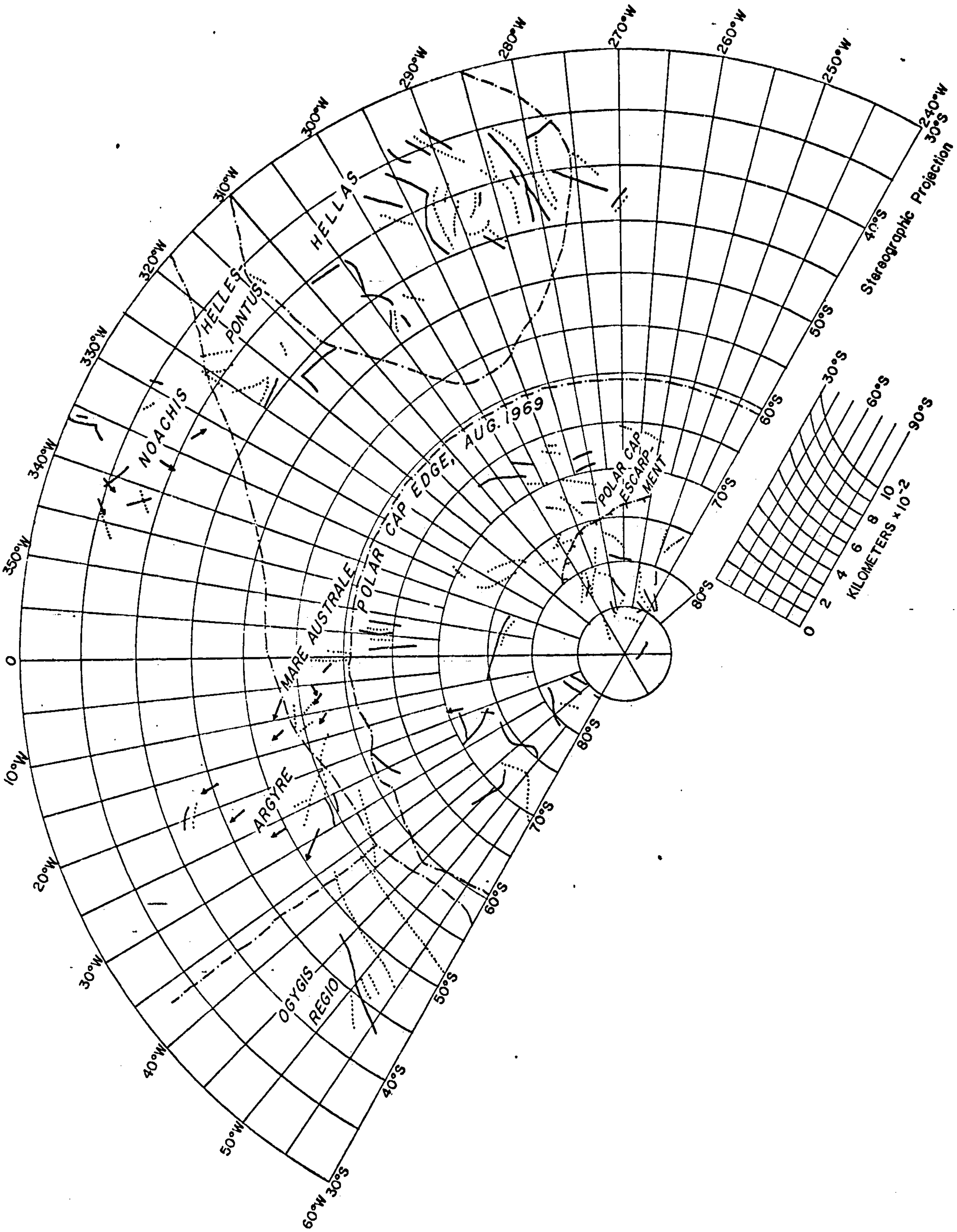
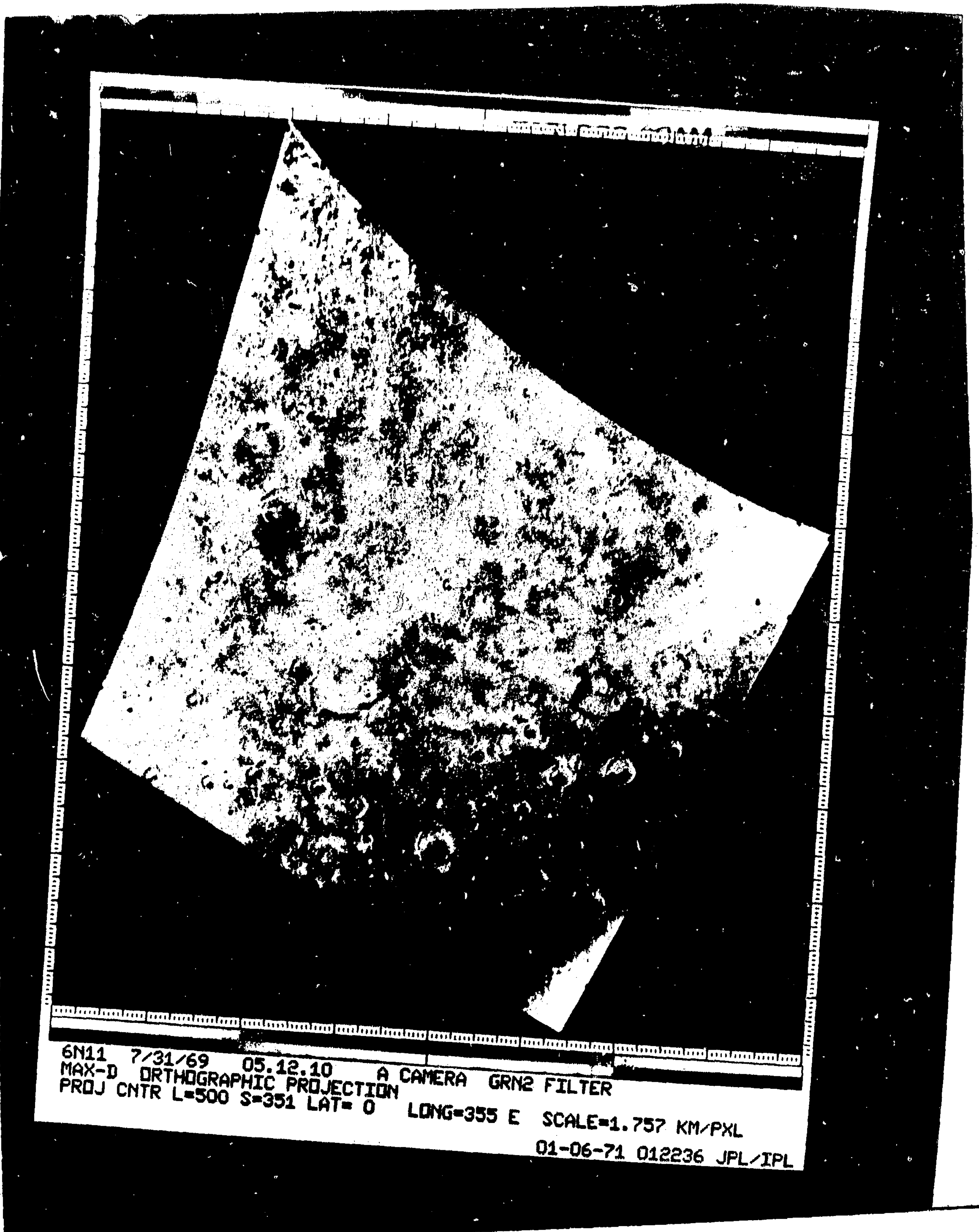

20° N
10° N
0
10° S
20° S
30° S
60°W
50°W
4?°W
30°W
20°W
10°W
0
350°W
340°W
EDEN
EDOM
XANTHE
CHRYSE
MAR-
GARITI-
FER SINUS
AURORAE
SINUS
SABAEUS SINUS
DEUCAL- IONIS
REGIO
MARE
ERYTHRAEUM
Mercator Projection
EXPLANATION
Streaks:
Light
Dark
Directional Features
Province Boundaries
30°
0°
0 2 4 6 8 10
KILOMETERS × 10^-2

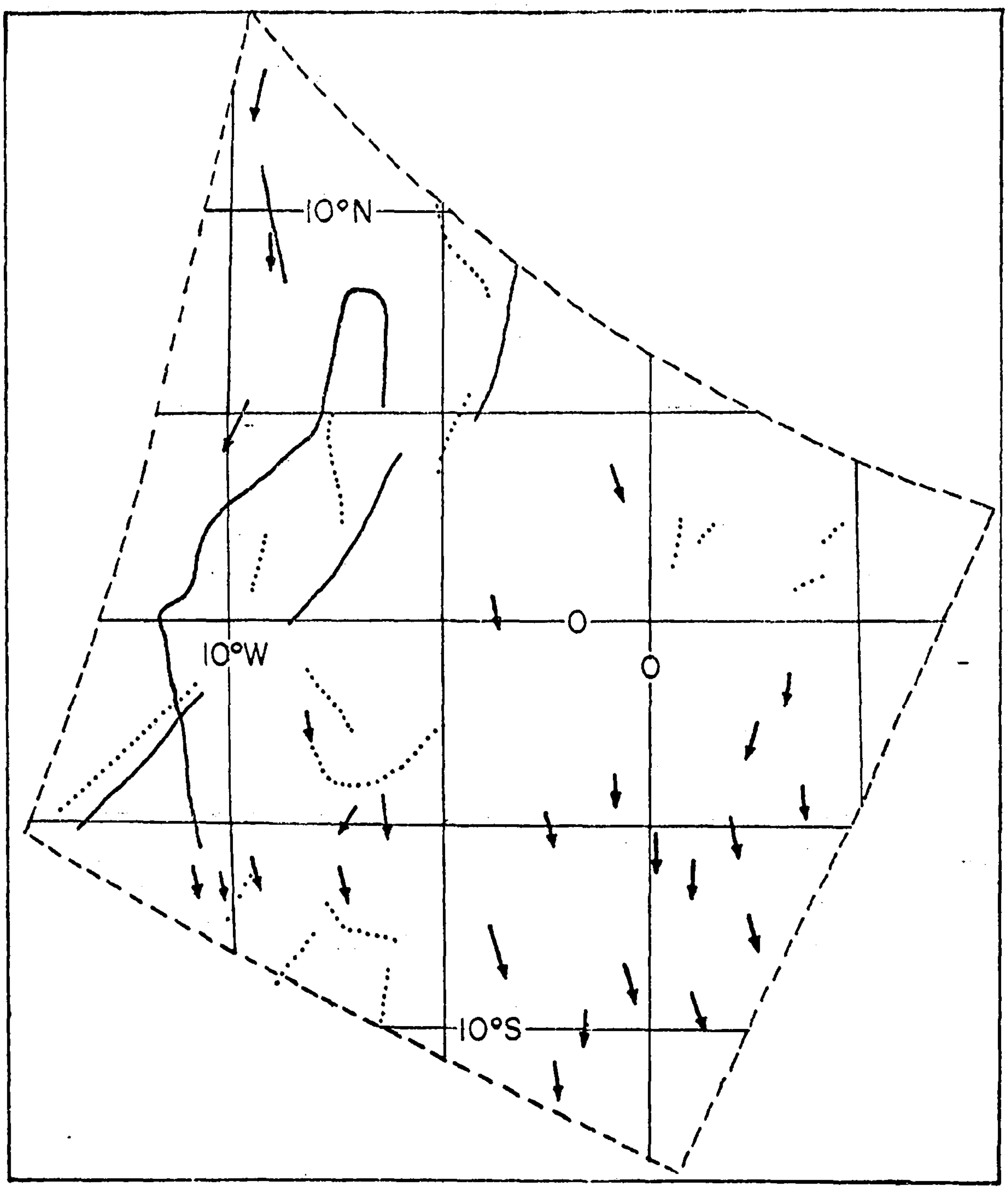
Figure 2. Wind directions in the southern latitudes of Mars interpreted from oriented surface features of probable eolian origin. See Figure 1 for explanation of map symbols.



Stereographic Projection
KILOMETERS x 10-2
0
2
4
6
8
10
30°S
60°S
90°S
HELLAS
HELLES PONTUS
NOACHIS
POLAR CAP EDGE, AUG. 1969
POLAR CAP ESCARP-MENT
MARE AUSTRALE
ARGYRE
OGYGIS REGIO
240°W 30°S
250°W
260°W
270°W
280°W
290°W
300°W
310°W
320°W
330°W
340°W
350°W
0
10°W
20°W
30°W
40°W
50°W
60°W 30°S
40°S
50°S
60°S
70°S
80°S

Figure 3. Orthographically-corrected maximum contrast picture 6N11 in the Meridiani Sinus region and the map of oriented surface features interpreted from this picute. The features on this map do not exactly agree with those on Figure 1 in the same region because 1) several photographs of this region were used to produce Figure 1, and 2) some editing was required for the small scale of Figure 1. See Figure 1 for explanation of map symbols.


6N11 7/31/69 05.12.10 A CAMERA GRN2 FILTER
MAX-D ORTHOGRAPHIC PROJECTION
PROJ CNTR L=500 S=351 LAT= 0 LONG=355 E SCALE=1.757 KM/PXL
01-06-71 012236 JPL/IPL



10°N
10°W
0
0
10°S