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GEOMORPHIC EVIDENCE FOR ANCIENT SEAS ON MARS

by

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The discovery of large outflow channels on Mars has posed complex and outstanding problems with regard to their formation. Most channels empty into large, seemingly featureless plains with little apparent evidence of the depositional morphologies to be expected with the debouchment of enormous volumes of sediment, as implied by the physical scale of the outflow channels. Hypotheses have never reconciled volumes and locations of proposed source regions with the observed sizes and implied discharges of the channels, nor have they adequately accounted for the apparent lack of obvious depositional features at outflow channel mouths.

The inability to identify fan or delta deposits at the mouths of the martian outflow channels at available resolutions does not preclude their existence (1), since such deposits are difficult to identify even in terrestrial examples of catastrophic outflow - for example, the Channeled Scablands of the Pacific northwest (2) and the Pleistocene glacial lake basins of the northern Great Plains (3). Apparently catastrophic deposition spreads material over a much larger outwash area than that of a typical river. On Mars this effect would be more pronounced due to the lower gravity (4).

The debouchment areas of major outflow channels and fretted terrains present an intriguing array of subtle morphologies, which, taken as a group, could plausibly argue for formation in a near-shore lacustrine environment. Some of these features are illustrated in figures 1-3, and are described briefly below.

Figure 1 depicts a region in southwest Cydonia Mensae (32^0 lat., 17^0 lon.), north of the lowland/upland boundary escarpment comprised of clusters of massifs and knobs, probably outliers of cratered upland material, and smooth lowland plains. Surrounding the clusters and linking many isolated knobs is a system of curvilinear ridges and arcuate terrain boundaries which tend to separate the knobby terrain and massifs from the smooth plains, the concave sides of the arcs facing toward the plains. This relationship is strikingly similar to terrestrial examples of islands linked by coastal barriers and tombolos and is of comparable scale.

Figure 2 depicts a degraded, 45 km crater at 33^0 lat., 23^0 lon., 300 km from the lowland/upland boundary escarpment in Acidalia Planitia. The crater rim has been modified into a loose, broken chain of knobs with low, roughly concentric debris aprons. This style of debris-aproned knob, or stepped massif, represents a morphology unique to the northern lowlands and may represent pre-flood material modified during a rise in base level during flooding of the northern lowlands. The debris aprons are rounded in plan, typically non-lobate, and could have formed either by wave action or mass wasting processes, or both. Further, they appear to have a smooth, nearly horizontal upper surface, often displaying sharp demarcations at slope inflections. These differ from massifs with debris aprons described elsewhere (5,6) in which the debris apron is often lobate in plan with a distinctly striated upper surface. Curvilinear ridges may occur in direct association with the stepped massifs, forming links between individual knobs, and appear to grade into the upper surfaces of the debris aprons.

Actual shorelines or strandlines would have to be very broad in order for them to be identified as separate features at typical Viking resolution, rather than as boundaries between morphologic units. Though very high resolution images (<15 m/pixel) are available, few coincide with areas in which this hypothetical shoreline might be expected. Figure 3 illustrates the best example of possible shoreline/strandline features we have found thus far. Figure 3a is a low resolution (200 m/pixel) mosaic of fretted terrain in west Deuteronilus Mensae, showing at least three zones parallel to the lowland/upland boundary, suggestive of increasing modification northward. The southern-most zone consists of sharply defined highland plateau material (zone "A"). The middle zone (zone "B") consists of well defined plateau material with a surface smoother than that of zone "A". The northern-most zone consists of rounded, softened plateau remnants and "striped" or mottled terrain (zone "C"). The floors of the canyons or "frets" also display at least 3 different zones, offset southward with respect to the plateau surface zones. Zone "A" consists of flat canyon floors bounded by prominent debris aprons. Zone "B" consists of flat floors lacking debris aprons. Zone "C" consists of striped or mottled terrain separated from zone "B" by an arcuate boundary. Figures 3b-e are part of a 9 m/pixel image mosaic centered at 46^0 lat., 346^0 lon., of part of the west canyon of figure 3a. In this mosaic, the northern extent of zone "B" of both the plateau and canyon floor have been resolved into polygonally patterned ground, the individual polygons measuring several tens to a few hundred meters across, similar or somewhat larger in scale than terrestrial ice-wedge polygons.

Several bands, visible along the canyon wall and within the degraded 10 km crater to the west, appear to be topographically conformal features and may be strandlines. No polygonal terrain is visible north of the lowest of these bands where it separates the middle zone from the northernmost zone of the fretted terrain. The scale of these bands is similar to broad terrestrial strandlines and beach ridges.

These hypothetical lakes or a shallow sea or ocean may have persisted for a time period significant with regard to the erosion of promontory and bounding topography (e.g., flat-topped mesas and fretted terrain). While our assertions may appear provocative, they are consistent with very conservative estimates of martian global water inventories (7, 8), as well as with an emerging realization that thin, heavily sediment-laden flows may have spread out from channel mouths across the northern plains for hundreds of kilometers (9, 10, 11).

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Figure 1

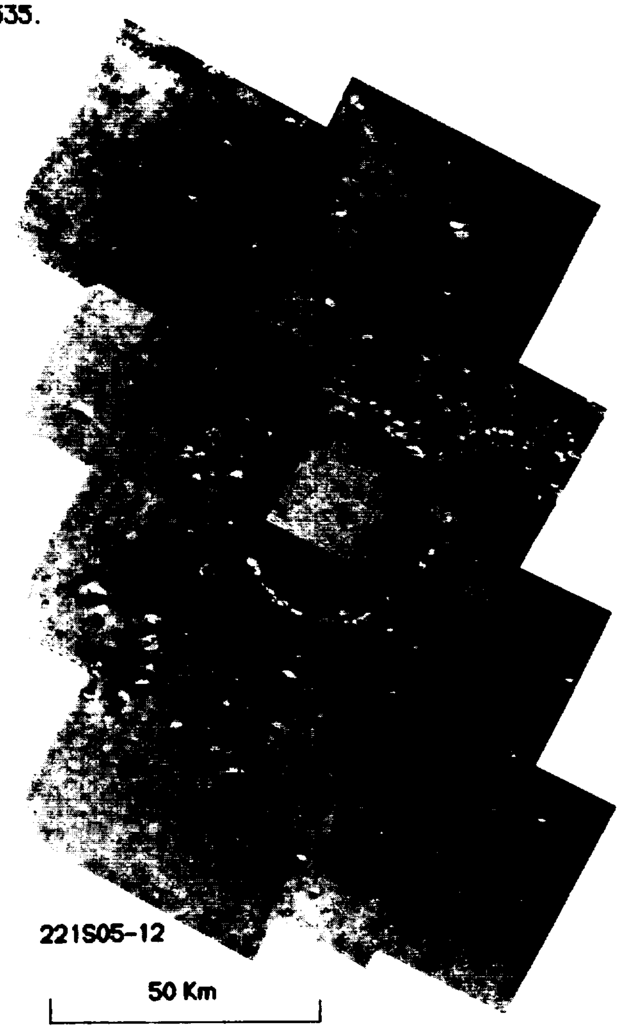

Figure 2

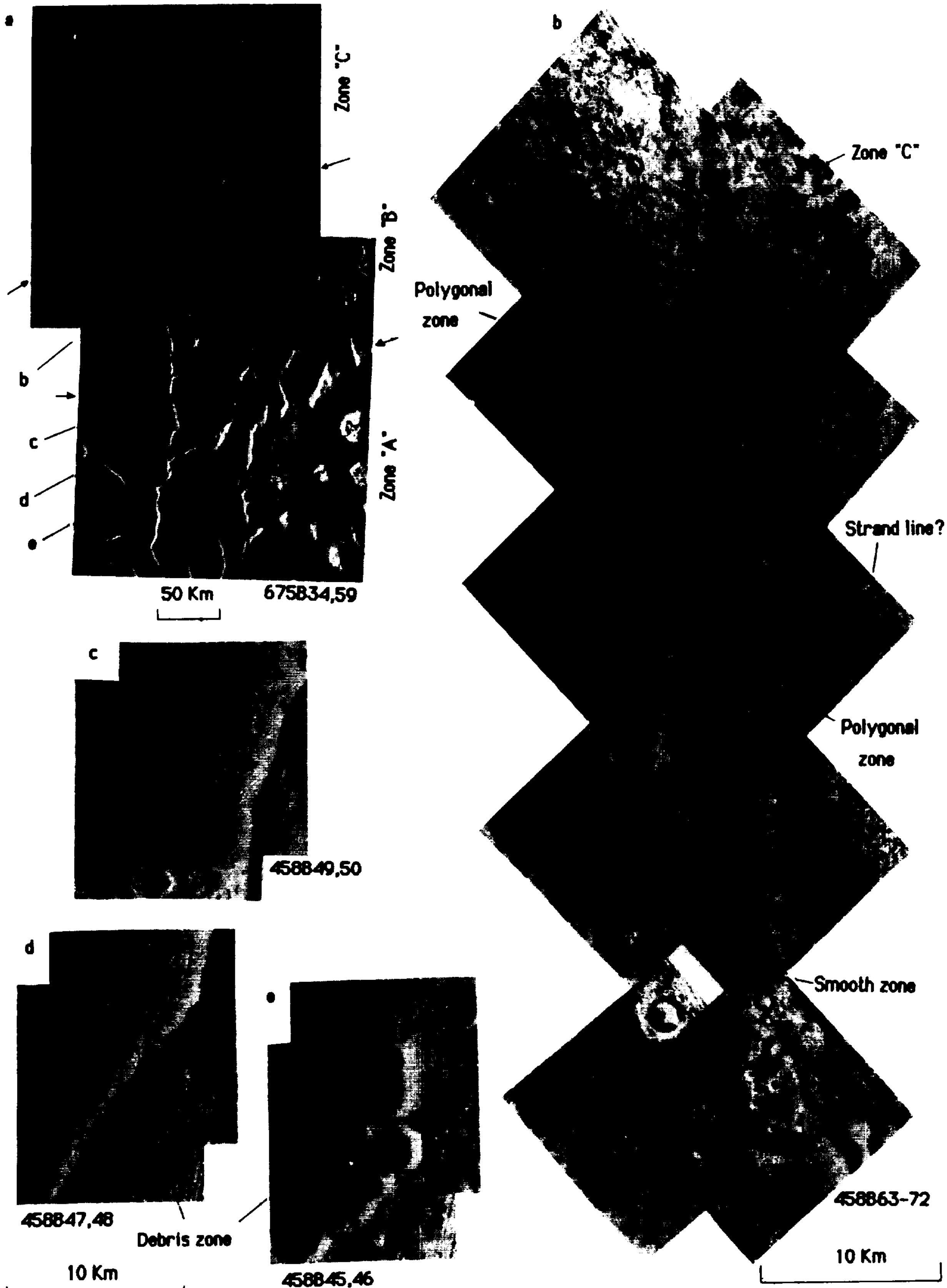
a
Zone "C"
Zone "B"
Zone "A"
b
c
d
e
50 Km
675B34,59
b
Zone "C"
Polygonal zone
Strand line?
Polygonal zone
Smooth zone
458B63-72
10 Km
c
458B49,50
d
458B47,48
Debris zone
e
458B45,46
10 Km

Figure 3