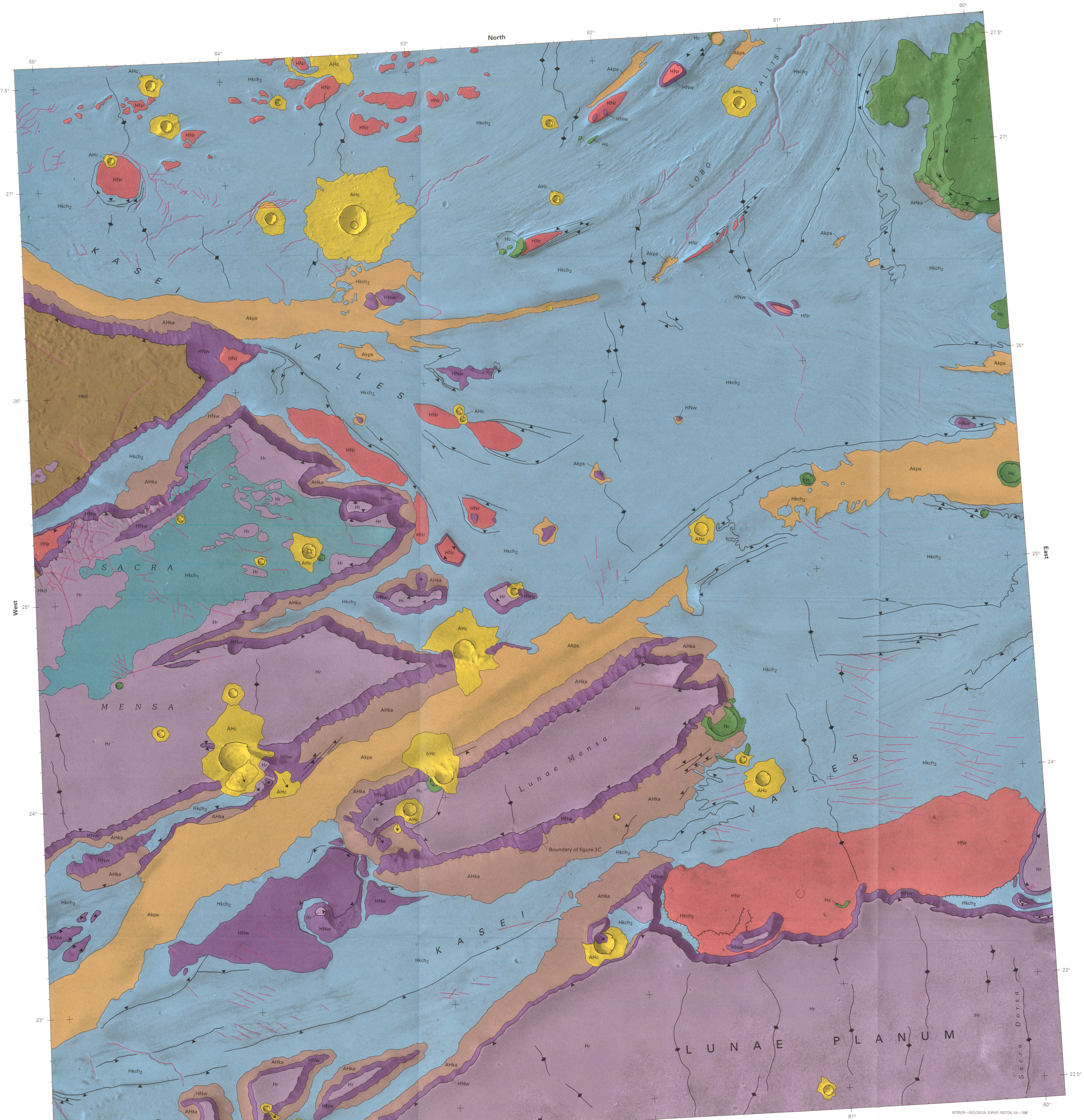
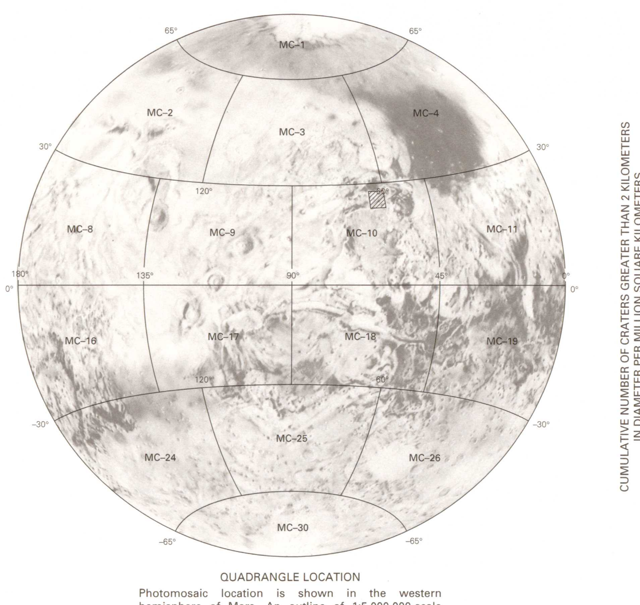
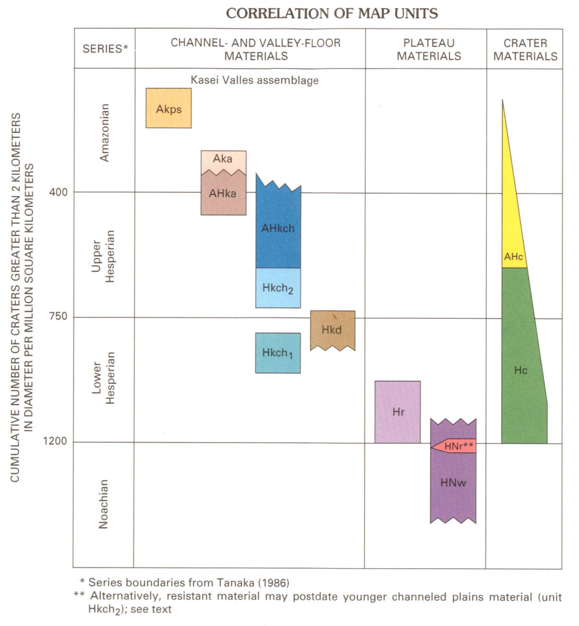
Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION







sis rise and northern Lunae Planum from Tempe Terra. In the vicinity of lat 20° N., long 75°, the broad, north-trending Kasei channel turns east and splits into two branches (informally referred to as the north and south channels) that extend eastward and then rejoin. Large mesas, including Sacra Mensa and the mesa covered by Sharonov crater (fig. 1), are found between the branches; the branches also anastamose around smaller mesas such as Lunae Mensa. Broad channel floors are generally 1 to 2 km lower than surrounding plateau surfaces, but floors of the narrow sections of the branches are locally more than 3 km lower than the plateau (U.S. Geological Survey, 1989).

STRATIGRAPHY

Stratigraphic positions of most geologic units and various structures and geomorphic features were determined by crater densities (fig. 2) and overlap and cross-cutting relations and placed in the global stratigraphic scheme of Tanaka (1986). Some stratigraphic assignments were based on previous work. The stratigraphic positions of erosional units represent the relative age of their surface modification (in contrast to ages of other units, which reflect their time of emplacement; see Milton, 1974). It is uncertain whether some units are erosional, depositional, or both.

Our detailed mapping has resulted in several previously unmapped units. Additionally, we have formulated the Kasei Valles assemblage, an informal grouping of channel deposits. The designation of this assemblage assists in distinguishing local channel units from others of similar age elsewhere on Mars, such as those of the Mangala Valles assemblage (Chapman and Tanaka, 1993).

NOACHIAN AND HESPERIAN SYSTEMS

Material exposed in the walls of Kasei Valles underlying Hesperian ridged plains material is mapped here as Hesperian-Noachian *wall material* (unit **HNw**). Layering within the unit is suggested by local alternating zones of contrasting albedo that occur along the walls of the plateau both in the map area (fig. 3*A*, *B*, *C*) and east of the map area at lat 23.2° N., long 59.3° (Scott, 1993). The prominence of these outcrops suggests that the layered zones have high erosional resistance. The layering has led to two stratigraphic interpretations of the unit: (1) It is a thick sequence of lava flows (Hesperian ridged plains material), perhaps interbedded with weaker materials, such as sedimentary deposits that were locally rich in ice (fig. 4*A*; Chapman and Scott, 1989; Scott, 1993); or (2) it is a sequence of Noachian impact breccia and other deposits, including resistant lava flows in places, that was modified by ground ice and secondary processes and capped by a thinner section of Hesperian ridged plains material (fig. 4*B*; discussed in more detail in Tanaka and Chapman, 1992). The former interpretation seems likely if one considers that the areal extent of the ridged plains lava flows rivals that of major plateau basalts on Earth and may likely have a comparable thickness of a kilometer or more rather than a few hundred meters. The map area contains no observable contacts on which the latter interpretation can be based; however, the base of Hesperian ridged plains material (lava flows) may be only several hundred meters below the surface of Lunae Planum, as suggested by calculated depths of buried Noachian impact crater rims (minimum of 600 m, De Hon, 1985) and measured depths of the inferred base of resistant ridged plains material (Davis and Golombek, 1990; Tanaka and Chapman, 1992). Because either interpretation is possible, we must assign this unit a Hesperian-Noachian age.

Another unit within Kasei Valles forms resistant caprock on channel-bank terraces and on flat-topped, streamlined islands on channel floors (fig. 5). This caprock has been mapped as *resistant material* (unit **HNr**). It appears to lie at a consistent elevation of about 1 km below the plateau surface. Our interpretation is that this layer occurs within the wall material and has been exhumed: it may be a zone of cementation or a buried lava deposit (fig. 4*B*; Tanaka and Chapman, 1992). A zone of cementation associated with the base of the cryosphere should be at about a 1-km depth, as suggested by thermal models (for example, Rossbacher and Judson, 1981). A mechanical discontinuity at this depth throughout the Kasei Valles and Lunae Planum region has been inferred from various measurements of erosional levels and structural geometries (Davis and Golombek, 1990; Robinson and Tanaka, 1990). According to the climate history recorded in the Martian highlands (Tanaka and others, 1988), the most favorable time for the formation of the proposed zone of cementation would have been the Early Hesperian, when the climate apparently cooled (Tanaka and Chapman, 1992). Permafrost in the upper kilometer of the crust may have then formed a barrier to ground-water circulation, and a zone where chemical precipitation was enhanced.

Alternatively, the unit could be lava flows or indurated flood deposits emplaced on a higher channel-floor level during or after an early episode of flooding, and the subsequent lowering of the surrounding plain could have occurred in a later channeling event (Tanaka and Chapman, 1992). Lava flows from Tharsis can be traced into northern Kasei Valles as far east as long 73° (Chapman and others, 1991), where they overlap the western outcrops of channeled plains material. The rough texture (at image resolution) of streamlined island caps is consistent in appearance with those flows; however, the western flows postdate the channeling (Scott and Tanaka, 1986). If the material is a flood deposit, its resistance to erosion might suggest that it is some type of cemented lag surface.

HESPERIAN SYSTEM

Ridged plains material (unit **Hr**) makes up widespread, smooth, plains-forming deposits marked by prominent wrinkle ridges (that resemble mare ridges on the Moon). The base of the unit defines the base of the Hesperian System on Mars (Scott and Carr, 1978). The unit includes the plateau caprock on Lunae Planum, on Sacra and Lunae Mensae, and on some smaller buttes within Kasei Valles. As discussed previously, the thickness of the unit has been estimated to range from several hundred meters to perhaps more than a kilometer (which would include much of the wall material of Kasei Valles). The unit has been interpreted to be made up of broad sheets of low-viscosity lava flows because of its resistance and wide distribution and the development of wrinkle ridges (Greeley and Spudis, 1981).

Kasei Valles assemblage

The Kasei Valles assemblage consists of sedimentary deposits that have erosional surfaces associated with two stages of flooding across Lunae Planum and Tempe Terra; the floods appear to have originated from Echus Chasma (fig. 1; Milton, 1974; Baker and Kochel, 1978a; Carr and Clow, 1981; Scott and Tanaka, 1986; Chapman and Scott, 1989; Robinson and Tanaka, 1990), from possible Tharsis sources (Jöns, 1986; Chapman and Scott, 1989; Tanaka and Chapman, 1992), and perhaps from Sacra Fossae (linear depressions on Lunae Planum; Tanaka and Chapman, 1992). The flooding was followed by local ground-water sapping and mass wasting and probably by eolian deposition. The units within the assemblage postdate ridged plains material and, thus, are Hesperian in age or younger.

Material of Sacra Mensa scoured and dissected by the first stage of flooding is mapped as the older *channeled plains material* (unit **Hkch$_1$**); no flood deposits associated with the scouring have been identified. The Early Hesperian age of the unit is verified by crater counts (fig. 2).

Where scouring was apparently deep, we have mapped *degraded plateau material* (unit **Hkd**), which has a rugged surface and appears chaotic. It may have formed by extensive removal of ground ice followed by collapse of overlying rock and sediment. The unit differs from more chaotic materials on Mars in that (1) it is not found in closed depressions, (2) it is adjacent to the channel rather than at the channel head, and (3) individual blocks typically appear to be smaller. The age of the unit is its degradational age. It is made up of either more friable ridged plains material or Noachian plateau material (see fig. 4).

A second stage of Kasei flooding carved the *younger channeled plains unit* (unit **Hkch$_2$**); throughout the map area, no channel deposits associated with this flooding have been confidently [illegible]

astrophic floods, perhaps because of the greater flooding power of the Kasei events (Robinson and Tanaka, 1990). Additionally, the Kasei crevices could have been enlarged by sapping, salt weathering, mass wasting, and eolian removal of detritus (Malin, 1976; Baker and Kochel, 1979).

GEOLOGIC SUMMARY

Prior to channel erosion of Kasei Valles, Lower Hesperian ridged plains material (probably interlayered lava flows) was deposited across Lunae Planum and Tempe Terra over older material of indeterminate origin and uncertain Noachian age. Wrinkle ridges deformed the plains material shortly thereafter. A zone of cementation at 1-km depth may have formed at the base of frozen ground. During Hesperian time, catastrophic flooding (or possibly glacierlike erosion) occurred in at least two episodes. The first period of flooding resulted from ground-water outbreaks probably from the east flank of the Tharsis rise and from Sacra Fossae. Early enlargement of Sacra Fossae by ground-ice sapping may have initiated the trough-and-mesa topography of the region. The troughs—as well as a preexisting gently sloping valley (fault controlled?) along the west edge of Lunae Planum (Scott, 1993)—may have controlled the course of the floods of the second episode. These floods issued from Echus Chasma and carved the deep Kasei canyons, including the narrow branch channels on the north and south sides of Sacra Mensa that locally exceed 3 km in depth and expose ancient plateau rocks. Later, at the end of the Hesperian and during the Amazonian, continued mass wasting and sedimentary activity within Kasei Valles resulted in (1) emplacement of debris aprons, consisting of coalesced alluvial fans, along the bases of mesas and plateau edges; (2) formation of rectilinear to sinuous grooves on channel floors due to enlargement of fractures by late-stage sapping; and (3) deposition of smooth plains material within the deep, inner channels of Kasei. Increased horizontal compressive stress caused by massive channel erosion produced wrinkle ridges that deformed the channel floor.

COMPUTER-GENERATED MAP OF MTM 25062 QUADRANGLE

The geologic map on this sheet was completed digitally on a Macintosh IIfx workstation with a RasterOps 19-in. color monitor. For comparison, the geologic map of MTM 25067 quadrangle, adjacent to the west (sheet 2), was produced by the usual manual means. Contacts between the two maps differ slightly due to the different production methods and minor mismatches of the bases.

The computer-generated map was produced in collaboration with Alex Acosta, U.S. Geological Survey, who has been developing digital methods to produce color geologic maps (Acosta and others, 1989; Acosta and Barrett, 1990). These mehtods eliminate most, if not all, manual tasks in the current labor-intensive and time-consuming peel-coat process of producing standard geologic maps. Mapping the MTM 25062 quadrangle by computer has provided input to the developing digital mapping system in the form of feedback from the authors. Although computer-based techniques do require additional time from the author for setting up a virtually press-ready product, the time required for editing, drafting, layout, and production is greatly reduced.

For the MTM 25062 quadrangle, contacts were drawn with Canvas (version 2.1.1, Deneba Software), because the program has vector capabilities and allows an unlimited number of layers (transparent overlays) and the import of large raster files. These features permit editing and the conversion of linework, geologic symbols, and geologic-unit labels to vector format.

The photomosaic map base was digitally assembled on a mainframe VAX computer system and converted to Macintosh-readable format by a program of Acosta's called PICSIMG. This photomosaic base was then imported into Canvas, and separate graphics layers were produced for contacts, structures, symbols, and unit names. Each graphic layer was then saved in an Encapsulated PostScript (EPS) format.

The geologic units were colored by importing the unit-contact layer into Photoshop (version 1.0.7, Adobe Systems Inc.), an image-processing program that allows the author to input unit colors as percentages on a CYMK (cyan, yellow, magenta, and black) scale to closely match the process ink color charts used by the U.S. Geological Survey. The colored file was then used to prepare an electronic "colored mill." The text, graphs, and illustrations were also generated on the workstation, saving the authors and cartographer the chore of time-consuming hand-drafting.

Finally, the EPS and electronic "colored mill" were supplied to the Thematic Mapping Section of the Geologic Division for processing. The map layout was defined and assembled in Illustrator. EPS data were used exclusively in generating the black-film separates, which included the contact linework, geologic symbols, geologic-unit labels, and collar information. The color data were processed using PosterWorks (version 3.0, S.H. Pierce & Co.), a program which separates color data into yellow, magenta, cyan, and black EPS formatted files. These files are then processed via a large-format imagesetter to produce process color film separates. All film separates were supplied to the printer.

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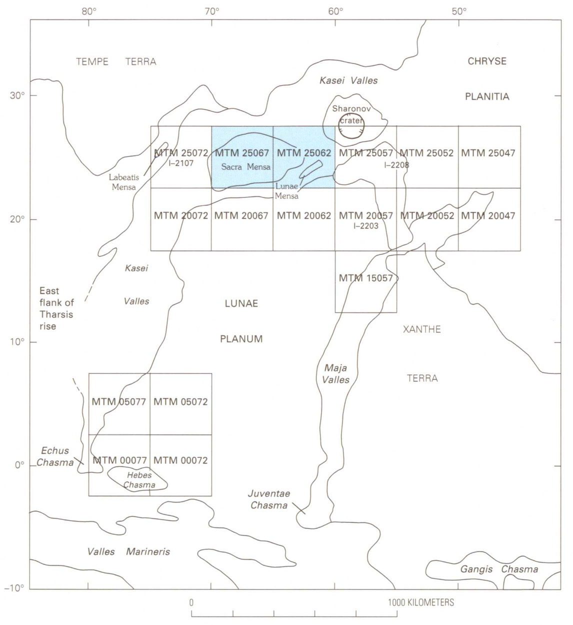

Figure 1. Index map showing location of maps.

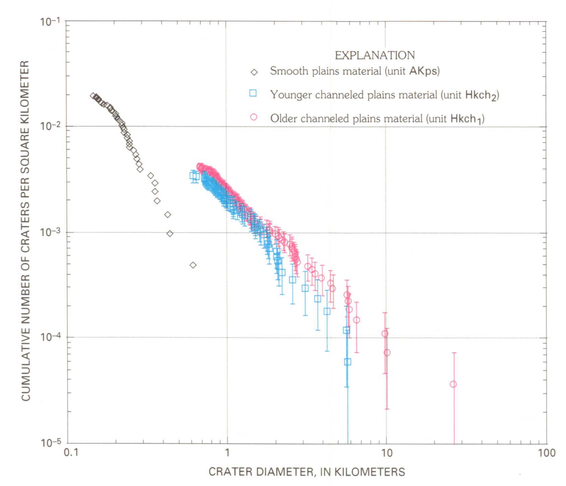

Figure 2. Log-log cumulative crater-density curves for principal geologic units in map area.

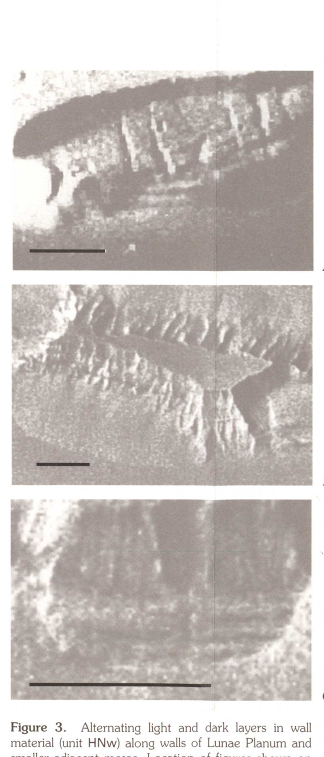

Figure 3.

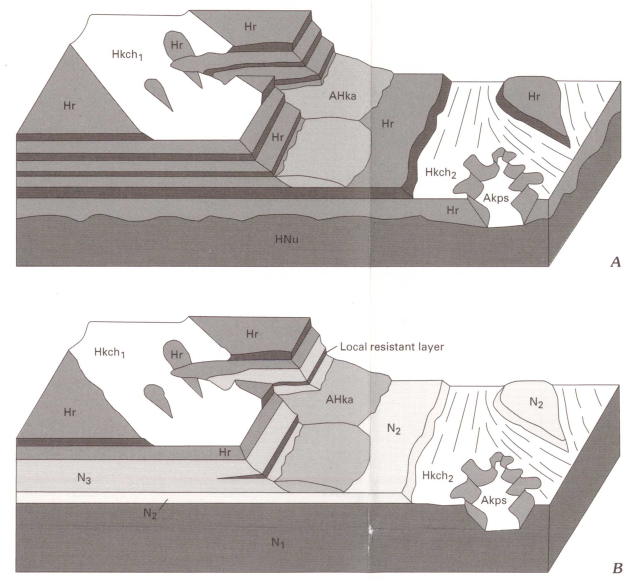

Figure 4. Block diagrams showing possible stratigraphies and erosional features interpreted for north Kasei Valles canyon system.

Figure 5.

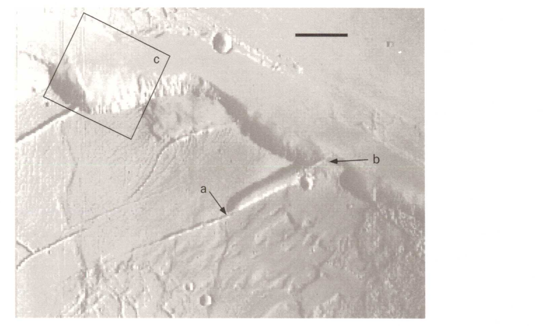

Figure 6.

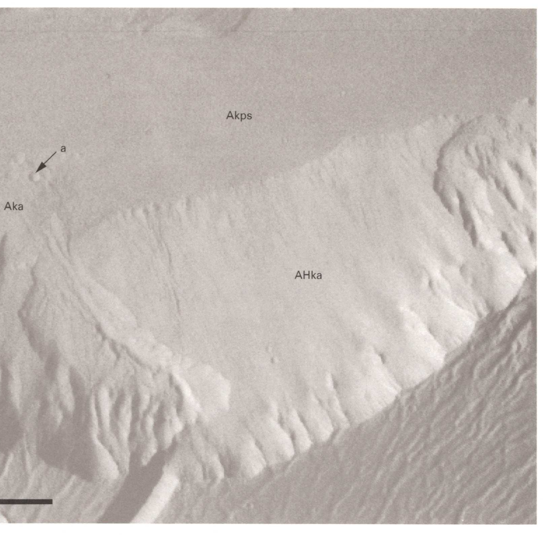

Figure 7.

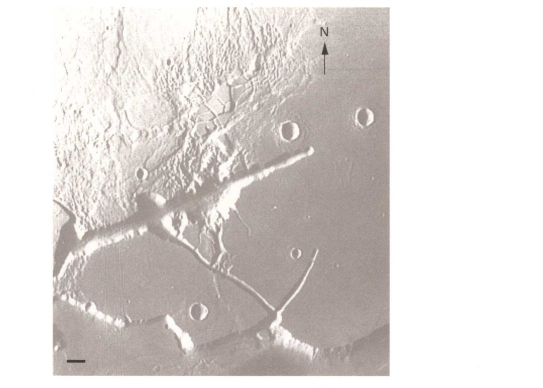

Figure 8.

Figure 9.

MTM 25062
GEOLOGIC MAPS OF THE MTM 25062 QUADRANGLE (DIGITAL COMPILATION) AND THE MTM 25067 QUADRANGLE (MANUAL COMPILATION), KASEI VALLES REGION OF MARS

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1996