U.S DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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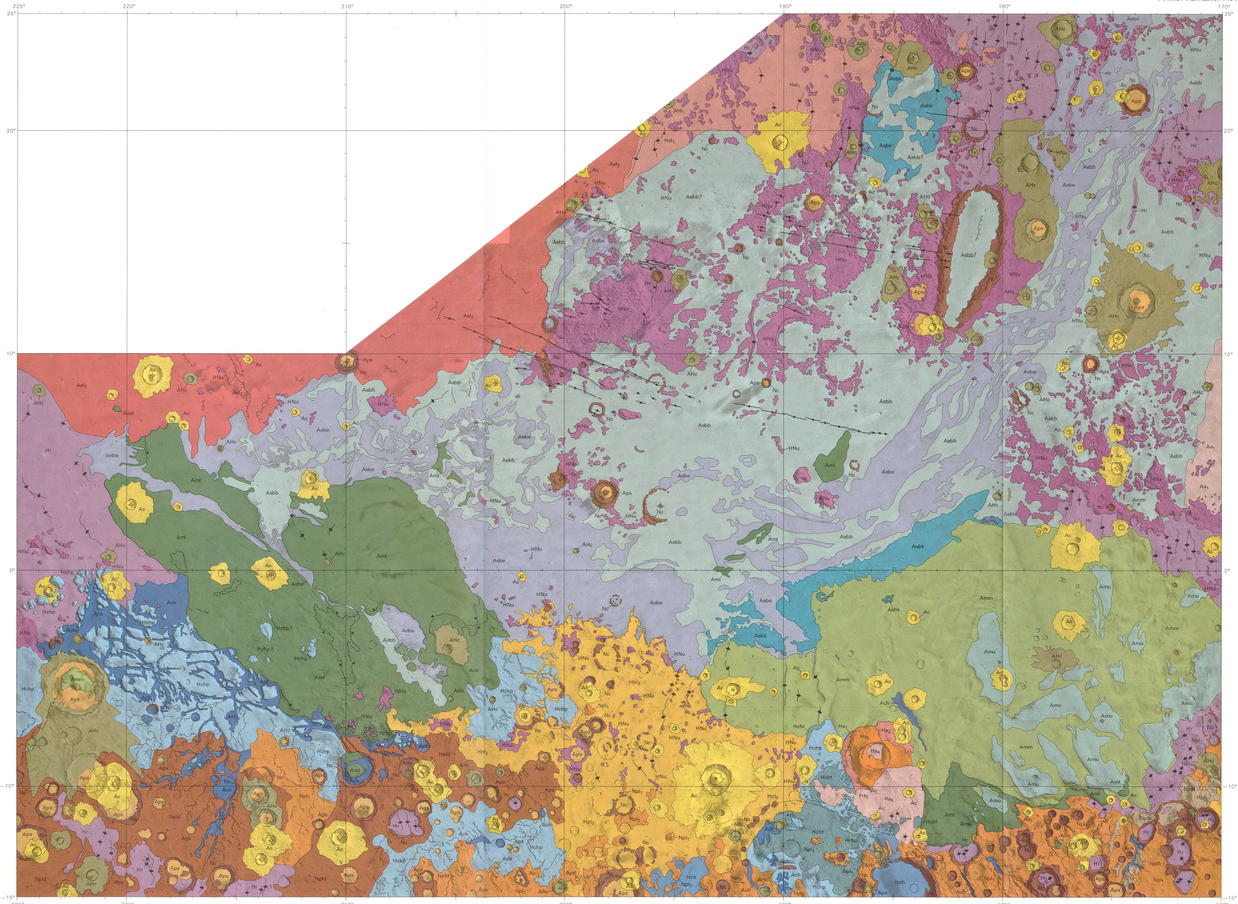
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:5,000,000 GEOLOGIC SERIES
ELYSIUM PALEOLAKE BASIN
M 5M, 5/197 G, 1995
MAP I-2397

GEOLOGIC

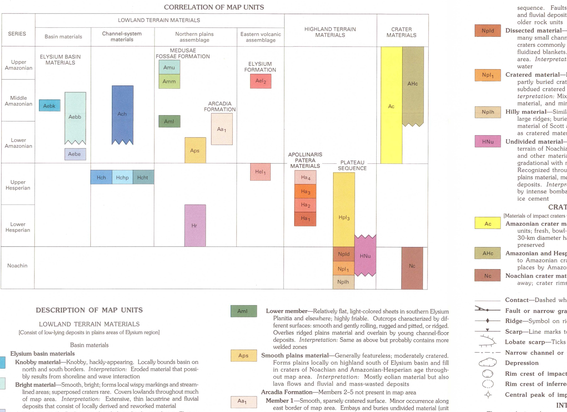


Base by U.S. Geological Survey (orbit data, 1989)

Data is a composite of U.S. Geological Survey (1989a, b and 1991a – e)

SCALE 1:5,000,000 (1 mm = 5 km) AT 0° LATITUDE
MERCATOR PROJECTION

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

LOWLAND TERRAIN MATERIALS

[Consist of low-lying deposits in plains areas of Elysium region]

Basin materials

Elysium basin materials

Aebb **Knobby material**—Knobby, hackly-appearing. Locally bounds basin on north and south borders. *Interpretation:* Eroded remnants of older rocks. May results from shoreline and wave interaction

Aeb **Bright material**—Smooth, bright, frequently scarping margins and stream-lined areas; superposed craters rare. Covers lowlands throughout much of map area. *Interpretation:* Extensive, thin lacustrine and fluvial deposits that consist of locally derived and reworked material

Aebe **Etched material**—Dark material underlying bright member in Elysium basin and outlet area (east of Orcus Patera); appears etched on high-resolution images and terminates in lobate fronts (Viking Orbiter image 38S065D). *Interpretation:* Lava flow; etching a possible result of lacustrine and fluvial erosion

Channel-system materials

Ach **Younger channel-floor material**—Found within channels that originate from highland south of Elysium basin. Unit overlies ridged plains material, and its channels cut older highland material, including lower and middle members of Medusae Fossae Formation. Channel courses may be dendritic or braided. *Interpretation:* Fluvial controlled. *Interpretation:* River-bed material that results from sapping

Hch **Older channel-floor material**—Smooth, flat surface dissected in places; few small ridges; albedo intermediate between Aeb and Ahc in Chryse and Ares and Al-Qahira Valles in southern part of map area. *Interpretation:* Fluvial deposits; local disintegration and collapse have contributed to dissection

Hchp **Channel plains material**—Generally smooth surface; embays dissected hills and mesas of chaotic material in low area west of Apollinaris Patera. Dissected by younger channels on highland in southwestern part of map area; gradational in places with smooth material (unit Hplg) of plains sequence. *Interpretation:* Channel and flood-plain deposits

Hchl **Chaotic material**—Forms irregular patches of hills and mesas of roughly uniform height rising above channel plains material southwest of Apollinaris Patera; elsewhere mapped as undivided material (unit HNu). In places unit appears gradational with hilly material (unit Nplh). *Interpretation:* A mélange of ancient highland rocks and Apollinaris flows disintegrated by melting of ground ice and dissected by flooding from channels in highlands and possibly by outflows from Ma'adim Vallis

Northern plains assemblage

[Widespread materials of northern plains]

Medusae Fossae Formation

Amu **Upper member**—Surfaces smooth, flat to rolling, light in color; scalloped into ridges and grooves; forms rounded mesas overlying middle member. *Interpretation:* Probably ash-flow tuffs, largely unwelded, possibly pyroclastic, paleopolar, or eolian materials; ridges may be yardangs controlled by joints (Ward, 1979)

Amm **Middle member**—Smooth, gently rolling surface with long, low, stream-lined ridges. Overlies lower member of formation. Elysium basin: Outposts, Apollinaris Formation, and channeled plains and chaotic materials; cut by young channel northeast of Apollinaris Patera. *Interpretation:* Same as above

Aml **Lower member**—Relatively flat, light-colored sheets in southern Elysium Plantita and elsewhere; highly friable. Outcrops characterized by different surfaces: smooth and gently rolling, smooth and dissected, or ridged. Overlies ridged plains material and overlain by young channel-floor deposits. *Interpretation:* Some members may be yardangs; others may be welded zones

Apa **Ridged plains material**—Generally featureless; moderately cratered. Forms plains locally on highland south of Elysium basin and fill in craters of Noachian age. *Interpretation:* Extensive plains material; see text and map area. *Interpretation:* Mostly eolian material but also lava flows and fluvial and lacustrine deposits

Arcadia Formation—Members 2–5 not present in map area

Aa$_1$ **Member 1**—Smooth, sparsely cratered surface. Minor occurrence along east border of map area. *Interpretation:* Eolian and lacustrine deposits

Aea **Etched material**—Dark material underlying bright member in Elysium basin and outlet area (east of Orcus Patera); appears etched on high-resolution images and terminates in lobate fronts (Viking Orbiter image 38S065D). *Interpretation:* Lava flow; etching a possible result of lacustrine and fluvial erosion

Ahr **Ridged plains material**—Forms smooth plains marked by long, broad wrinkle ridges that trend mostly north and northwest; moderately cratered. Embays knobby of undivided material (unit HNu), overlain by Medusae Fossae and Elysium Formations. *Interpretation:* Lava flows

Eastern volcanic assemblage

Elysium Formation—Volcanic materials associated with Elysium Mons, Hecates Tholus, Albor Tholus, and Elysium Planitia (Scott and Chang, 1992)

Aelz$_2$ **Member 2**—Flows moderately fractured, pitted, and cratered; flow scarps and channels common. Many impact-crater blankets have radial or fladed textures, suggesting presence of early lava flow surface. Widespread northwest of map area, covering most of Elysium rise and part of surrounding plains. Embays knobby of undivided material (unit HNu), and dissected features. Unit embays older flows and ridged plains material and appears to overlie younger channel materials. *Interpretation:* Lava flows; tributed to dissection

Hel$_1$ **Member 1**—Broad, lobate, smooth flows in northern part of map area; some wrinkle ridges. Overlain by knobby and bright Elysium basin materials; overlies ridged plains material. Unit not recognized by Greeley and Guest (1987). *Interpretation:* Friable lava or pyroclastic flows

HIGHLAND TERRAIN MATERIALS

Apollinaris Patera materials

Hpg **Unit 4**—Two occurrences. Smooth flow covers much of caldera floor of Apollinaris Patera; fan-shaped flow covers south flank. Latter flow is radially furrowed and ridged, contains wrinkle ridges in lower part; covers basal scarp and other scarps on flanks of volcano. *Interpretation:* Youngest lava flow on Apollinaris

Hpg$_3$ **Unit 3**—Forms upper flanks of Apollinaris; evenly spaced grooves extend down valley floor, steeper part of structure. *Interpretation:* Lower part of unit consists of lava flows, upper part of lava and pyroclastic material

Hpg$_2$ **Unit 2**—Smooth to hackly surface; conspicuous valleys and ridges in northeastern exposure; scarp marks most of basal contact. *Interpretation:* Lava flows, deeply eroded in places; scarps possibly those of faults that postdate lava flow; disintegration of unit may have formed some chaotic material

Hpg$_1$ **Unit 1**—Surface appears smooth to hummocky. Low basal scarp separates unit from channeled plains material. *Interpretation:* Lava flow similar to unit 2

Plateau sequence

Hplg **Smooth material**—Forms broad, flat, relatively featureless highland plains south of Elysium basin; locally embays other units of plateau sequence. Faults and flow fronts rare. *Interpretation:* Eolian and fluvial deposits and some lava flows that bury or embay most older rock units

Npld **Dissected material**—Highly cratered, uneven surface dissected by many small channels and marked by grabens and ridges. Older craters commonly rimless, lack visible ejecta; younger craters have fluidized blankets. Forms plateau in southeastern part of map area. *Interpretation:* Early crustal material eroded by wind and water

Nplr$_2$ **Cratered material**—Rough, irregular surface; displays buried and partly buried crater rims; locally cut by small valleys. Includes subdued cratered plains and smooth plains (unit Npl$_1$). *Interpretation:* Mixture of lava flows, impact breccias, crater-rim material, and minor eolian deposits

Nplh **Hilly material**—Similar to cratered material but contains peaks and large ridges; locally embays cratered material. Includes Noachian knobby material of Scott and Chapman (1991a). *Interpretation:* Same as cratered material but more tectonic deformation

HNu **Undivided material**—Knobby remnants of ancient heavily cratered terrain of Noachian age interspersed with mass-wasted products and other materials of Hesperian and younger age. In places gradational with material of large, highly degraded crater rims. Recognized throughout map area. *Interpretation:* Largely by ridged plains material, members of Elysium Formation, and Elysium basin deposits. *Interpretation:* Ancient crustal material contaminated by intense bombardment and degraded by removal of ground-ice cement

CRATER MATERIALS

[Materials of impact craters; rim diameters are larger than 10 km]

Ac **Amazonian crater material**—Superposed on Amazonian and older units; fresh, bowl-shaped craters; many craters larger than about 30-km diameter have central peaks; ejecta blankets generally well preserved

AHc **Amazonian and Hesperian crater material**—Similar in appearance to Amazonian crater material, but craters appear embayed in places by Amazonian and Upper Hesperian units

Nc **Noachian crater material**—Ejecta blankets largely buried or eroded away; crater rims subdued; many craters have central peaks

Contact—Dashed where approximately located or gradational

Fault or narrow graben

Hole—Symbol on edge crest

Scarp—Line marks top of slope; barb points downslope

Lobate scarp—Barbs on lower side; dashed where buried

Narrow channel or rille

Depression

Rim crest of impact crater—Well preserved and defined

Rim crest of inferred impact crater—Highly degraded or buried

Central peak of impact crater

INTRODUCTION

These geologic and topographic maps follow a basin in the Elysium region of Mars that is thought to have been the site of a large paleolake during the most recent period (Amazonian) in Mars' history (Scott and Chapman, 1991b). The basin, referred to as the Elysium Basin, is located at 0°–25° N. and 180–225° E. and covers about 1 million km^2. It is important, not only geologically, but because the amount, location, and distribution of liquid water in the map area contained would have been critical factors governing the possible origin and survival of life on Mars.

The Elysium basin is the only large depositional basin on Mars where direct evidence, both geological and topographic, of long-lived standing water has been found. However, indications of possible paleolocrites have been observed in several other areas on the highland-lowland boundary (described under Geologic and Physiographic Setting; Parker and others, 1989; De Hon and Pieth, 1992; Scott and others, 1992). Our mission of the Elysium basin, is twofold: two objectives, to determine (1) the maximum extent of the basin and (2) the former volume of water in the basin and the sources of this water. To fulfill these objectives, we have compiled this set of maps. The geologic map shows source channels and associated materials, and the topographic map shows the paleolake, on a new topographic base, shows former shorelines and drainage channels.

Our base maps are composites of complete or partial eight 1:2,000,000-scale subquadrangle maps made from Viking Orbiter 1 and 2 mosaics in scale. Although both of our maps have the same latitude and longitude grids, locations of some phyiographic features do not correspond. The geologic map overlaps the southeastern part of the geologic map of Tanaka and others (1992, fig. 1). Some geologic units are common to both maps, but minor changes have been made in the overlap area. Parts of the Elysium region were previously mapped at 1:5,000,000 scale, showing Chryse Planitia (Chryse Planitia Series, 1976; Morris and Dwornik, 1978; Scott and others, 1978; Mutch and Morris, 1979).

The present maps are an outgrowth of previous large-scale geologic mapping in the Memnonia quadrangle (Scott and Chapman, 1991a), which showed a young (Amazonian) outflow channel associated with the postulated sub-flow tuffs of the Medusa Fossae Formation. If the channel originated from the melting of ground ice by the ash flows, why had no other channels been found around the margins of the formation? This question led to the mapping at 1:2,000,000-scale photomosaic quadrangles that surround the mapped extent of the Medusae Fossae Formation (Scott and Tanaka, 1982, 1986; Greeley and Guest, 1987) and the adjacent Elysium basin. Our studies showed many small channels originating in the formation and extending northward into the lowland plains; other channels lying east of the map area drained into Amazonis Planitia to the northeast (Scott and others, 1992).

The north-trending channels may have been primary water sources for the Elysium basin. Tanaka and Scott (1986) had attributed inflow to the basin to a few small channels on its north side, but the channels seemed inadequate to account for the large accumulation of water that may have once filled and overflowed this vast reservoir. Geologic relations shown on the map suggest that a large amount of water must have come from highland sources to the south as both surface-water and ground-water flow systems.

GEOLOGIC AND PHYSIOGRAPHIC SETTING

The Elysium basin is mostly lower than -1,000 m in elevation and lies at the base of a gentle slope that extends southward from Elysium Mons (outside the map area; fig. 1). The floor of the basin has a generally moderate albedo and is marked by light-colored, wispy zones that differ in appearance from local wind-streak patterns. These zones and other streamlined features appear to be primary markings that indicate flow direction from the basin. The basin is about 750 km wide in its central part, but it narrows to about 200 km east of Orcus Patera (fig. 1) near its spillpoints into Amazonis Planitia. Spillpoint elevations are well above the basin floor. Thus, the basin has been partly drained at these places. Channel bars or islands, terraces, and streamlined albedo patterns can be seen in this narrow region. These two channels, which are larger than Ares Vallis (Scott and Tanaka, 1982; Scott and Tanaka, 1982; Greeley and Guest, 1987), indicating an Amazonian age. Most craters larger than about 1 km in diameter appear embayed by sedimentary deposits, which suggests that the sediments are only tens of meters thick (Tanaka and Scott, 1986) but the stratigraphic relations. A large crater (Gusev) at the end of the channel may have ponded flow from Ma'adim, and other percolation through highly permeable crater materials the waters may have emerged downstream as seepage that formed channeled plains.

After the Early Hesperian formation of Athor Tholus and Elysium Mons (fig. 1), lava flows of member 2 of the Elysium Formation (unit Hel$_2$) covered ridged plains in eastern Elysium Planitia (Tanaka and others, 1992). Moderate to severe erosion of member 1 has left some remnant outcrops and produced a pedestal morphology around a few impact craters outside the map area. Degradation of the unit may have been due to inherent material weakness, possibly indicating a pyroclastic composition, or to volcano/ground-ice interactions.

The craters of *Amazonian and Hesperian crater material* (unit AHc) have relatively sharp rim crests and broad ejecta blankets compared with Noachian craters. They are embayed by Amazonian materials and appear to be both embayed and overlapped in places by Hesperian rocks.

AMAZONIAN SYSTEM

Tectonic, volcanic, and fluvial activity during the Amazonian was largely restricted to two volcanic centers: Elysium Mons and, east of the map area, the Tharsis complex. Fluvial activity in Amazonian time was confined to local channels is more evident at Elysium than at Tharsis. The Early Amazonian was particularly eventful about half the map area was covered with lava flows that were emplaced or acquired their present forms during this epoch.

Within the Amazonian, two depositional systems in the map area are exposures of Lower Amazonian *smooth plains material* (unit Apa), which may partly consist of eolian and fluvial deposits. Smooth plains material also occurs on large crater floors. Also included in this assemblage are lobate lava flows of member 1 of the *Arcadia Formation* (unit Aa$_1$) that postdate the paleolake. Lobate lava flows at the map area, and the *lower, middle, and upper members of the Medusae Fossae Formation* (units Aml, Amm, and Amu), which were emplaced before and after. The Medusae Fossae surfaces are flat to gently convex and, unlike lava flows, do not show lobate margins or flow features on their margins. The respective stratigraphic positions of the members are generally clearly shown by overlap relationships. The formation has been eroded by wind into flutes and yardangs (Ward, 1979), which in places appear to follow complementary cooling joint sets (Scott and Chapman, 1991a), similar to those in the more eroded zones of terrestrial ignimbrites (Scott, 1969). The formation makes up a broad flat discontinuous terrace that rises several hundred meters above the surrounding area from long 127° to 221° (Scott and Tanaka, 1982, 1986). Stratigraphic relations and crater counts of the members indicate an Early to Late Amazonian age. On the basis of its morphologic characteristics, the Medusae Fossae Formation has been interpreted to consist of ash-flow tuffs (Malin, 1979; Ward, 1979; Scott and Tanaka, 1982, 1986). Other investigators, however, have considered it to be ancient polar deposits (Schultz and Lutz, 1988), carbonate (Pollack, 1979), or pyroclastic and eolian materials (Lucchitta and others, 1982; Thomas, 1982; Greeley and Guest, 1987). Features resembling terraces or pondels along the lower margin of the formation (fig. 2) may have been eroded by Elysium basin waters. However, the middle and upper members to the east show no such erosion and have formed after older units (Scott and Tanaka, 1982).

On the gently dipping southeast flank of the Elysium rise, faults of Cerberus Rupks follow older west-northwest trends of the highland-lowland boundary in this region. These faults may have provided conduits for the dike intrusions the Elysium basin (fig. 3; Plescia, 1990). Although Plescia described the dark material as young volcanic material, the material is cratered and has been emplaced on high-resolution images to be very similar to lava flows etched and eroded by water (fig. 4). Scott and Chapman, 1991a) interpreted the unidivided material (unit HNu), which has been infilled by debris and younger materials through Early Hesperian time (Scott and Tanaka, 1982; Greeley and Guest, 1987; Maxwell and Craddock, 1988) and later, until the Late Amazonian, by deposits of the Elysium basin (Tanaka, 1986). Although most of the lava flows in the Elysium basin flow are radar bright and are likely lava flows (Harmon and others, 1992). The flows may have resulted from volcanism related to the Elysium Mons, Albor Tholus, and the Middle Amazonian, widespread volcanism had ceased on the Elysium rise and in the adjoining basin (except for emplacement of the Elysium Formation). If the Elysium lake had a thick ice cover, the ice may have prevented rapid evaporation of the water.

Did the Elysium basin contain an intermittent or a persistent lake system? Three different ages of inflow from channel systems into the basin suggest the recurrence of a lake. Initially, when Mars retained a thicker atmosphere before the formation of the basin and the Elysium volcanic rise, many small dendritic channels of Noachian age probably drained from the highlands into a broad lowland plain. During Hesperian time, after basin had become well defined, large outflow channels such as Ma'adim and Al-Qahira Valles formated highland waters into it Hesperian and Early Amazonian. The basin floor during this time is indicated by channels within the Medusae Fossae Formation that drained toward the basin and by the drainage of water into the basin from the north, which cut streamlined features in Amazonian volcanic flows of the Elysium rise such as those at lat 9° N., long 204° (Viking Orbiter image 883A30).

The presence of large quantities of water at and near the surface of Mars has important implications for geological and biological evolution, and the existence of the water in the past is suggested by growing evidence (Scott, 1982; Haberle, 1986; Carr and others, 1987; Sagan and others, 1989; Parker and others, 1989; Scott and others, 1990). Although existence of a global ocean covering the Martian lowlands (Lucchitta and others, 1985, 1986; Parker and others, 1989; Baker and others, 1990) may be difficult to establish, ephemeral seas or large lakes are now thought to have occupied depressions along the foreland region of the highland plateau (Parker and Saunders, 1988; Scott and others, 1990). Most of this water probably flowed through large outflow channels such as those around the Chryse basin; estimates of water volume were based on the volume of materials eroded during the formation of these channels (Carr, 1986; Carr and others, 1987).

The Elysium basin is especially important for quantitative determinations of water volume, because the presence of spillways around its perimeter is direct evidence (geologic and topographic) of a high water level. (Overflow may have also occurred to the west.) Moreover, Elysium is a large but relatively shallow depression. Incoming sediments were probably insufficient to bury organic communities, if such existed, before they became established (Des Marais, 1988). Ice-covered lakes could have held liquid water at about 0°C that may have significantly extended the period when biological habitats could persist (McKay and others, 1985; Wharton and others, 1987; McKay and Nedell, 1988). Gas-concentration measurements made from Viking Lander 1 indicate that present atmospheric gases and provided a source of biologically important gases (principally CO_2 and N_2) as the Martian atmosphere continued to thin (McKay and Stoker, 1989).

GEOLOGIC SUMMARY

1. Early Noachian: Formation of northern lowlands.
2. Late Noachian: Deposition of lowland materials and highland material along highland-lowland boundary into knobby terrain; fluvial dissection of plateau material.
3. Early Hesperian: Emplacement of ridged plains material that possibly represents initial Elysium-centered volcanism; formation of broad, north-trending ridges in eastern Elysium Planitia due to Thareis isostatic loading; formation of Hesperian plateau material; early growth of Apollinaris Patera.
4. Late Hesperian: Widespread volcanism on Elysium rise; continued growth of Apollinaris Patera; channel development.
5. Early Amazonian: Deposition of Medusae Fossae Formation in southern Elysium Planitia and Memnonia Plateau; formation of Elysium basin; formation of Apollinaris Patera; Amazonian channels and fluvial erosion; formation of broad, north-trending ridges in eastern Elysium Planitia; isostatic loading; formation of Hesperian plateau material; early growth of Apollinaris Patera.
6. Late Hesperian: Widespread volcanism on Elysium rise; continued growth of Apollinaris Patera; channel development.
7. Early Amazonian: Deposition of Medusae Fossae Formation in southern Elysium Planitia and Memnonia Plateau; formation of Elysium basin; formation of Apollinaris Patera; Amazonian channels and fluvial erosion; formation of broad, north-trending ridges in eastern Elysium Planitia; isostatic loading; formation of Hesperian plateau material; early growth of Apollinaris Patera.
8. Middle Amazonian: Paleolake begins major growth mostly from large outflow channels and runoff from highlands.
9. Late Amazonian: Paleolake drains through outlets and evaporates; continuation of widespread volcanism on Elysium rise; final deposition of Medusae Fossae Formation.

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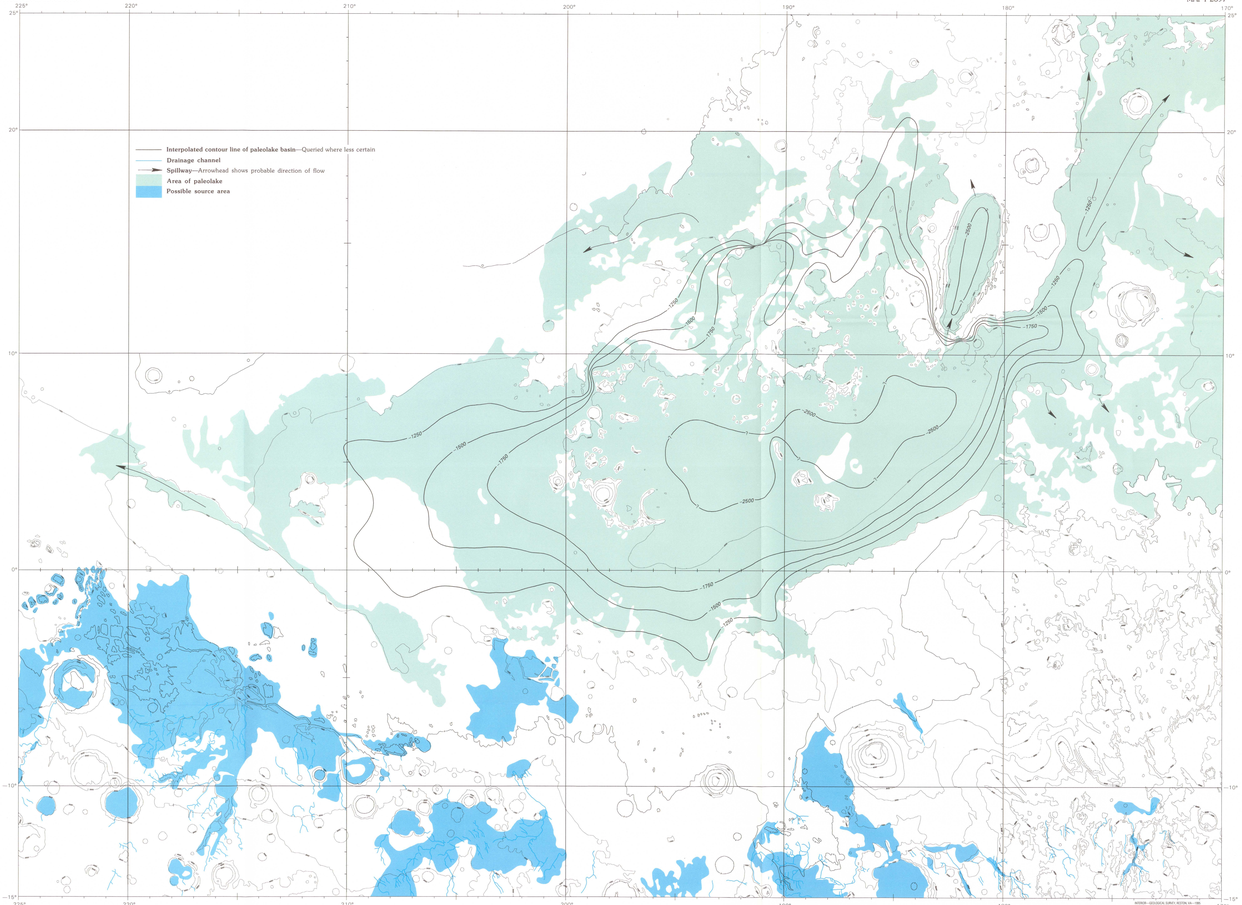
TOPOGRAPHY



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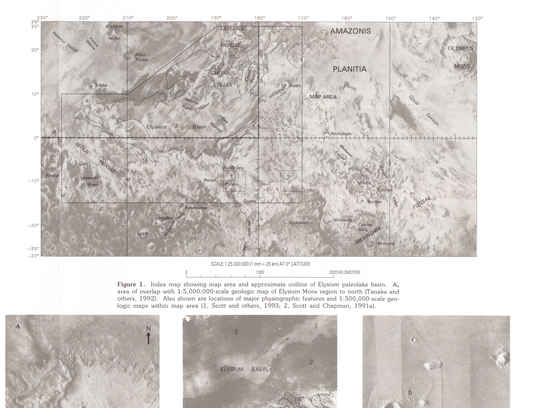

Figure 1. Index map showing map area and approximate outline of Elysium paleolake basin. A, area of overlap with 1:5,000,000-scale geologic map of Elysium Mons region to north (Tanaka and others, 1992). Also shown are locations of major physiographic features and 1:500,000-scale geologic maps within map area (I, Scott and others, 1993; 2, Scott and Chapman, 1991a).

Figure 2. Images illustrating eroded nature of lower member of Medusae Fossae Formation. Scale bars equal 10 km. A, Probable terraces cut into member (arrows) and eroded superposed crater. Viking image 596A03, resolution 237.60 m/pixel; image centered at lat 4° S., long 206°. B, Additional terraces (arrows); Viking Orbiter image 383S28; resolution 231.49 m/pixel; image centered at lat 5° S., long 213°.

Figure 3. Map units along southeast rim of Elysium basin. 1, knobby material; 2, etched material; 3, bright material. Middle member of Medusae Fossae Formation (unit Amm) overlies these units. Streamlined features (arrows) show flow from basin; small channels in knobby material shown by dark-blue arrows. Viking Orbiter 383S574; image centered at about lat 2° N., long 184.5°.

Figure 4. Images showing similar-appearing surfaces (probably lava flows) on Mars. A, Surface of dark etched material along south shoreline of Elysium basin. Viking Orbiter image 766A02; resolution 14.18 m/pixel; image centered at lat 2.19° N., long 195.94°; scale bar equals 5 km. B, Eroded floor of large crater embayed by material into Chryse basin. Viking Orbiter image 004A37; centered at lat 19° N., long 35° (outside map area); scale bar equals 10 km.

GEOLOGIC AND TOPOGRAPHIC MAPS OF THE ELYSIUM PALEOLAKE BASIN, MARS

By
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1995

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