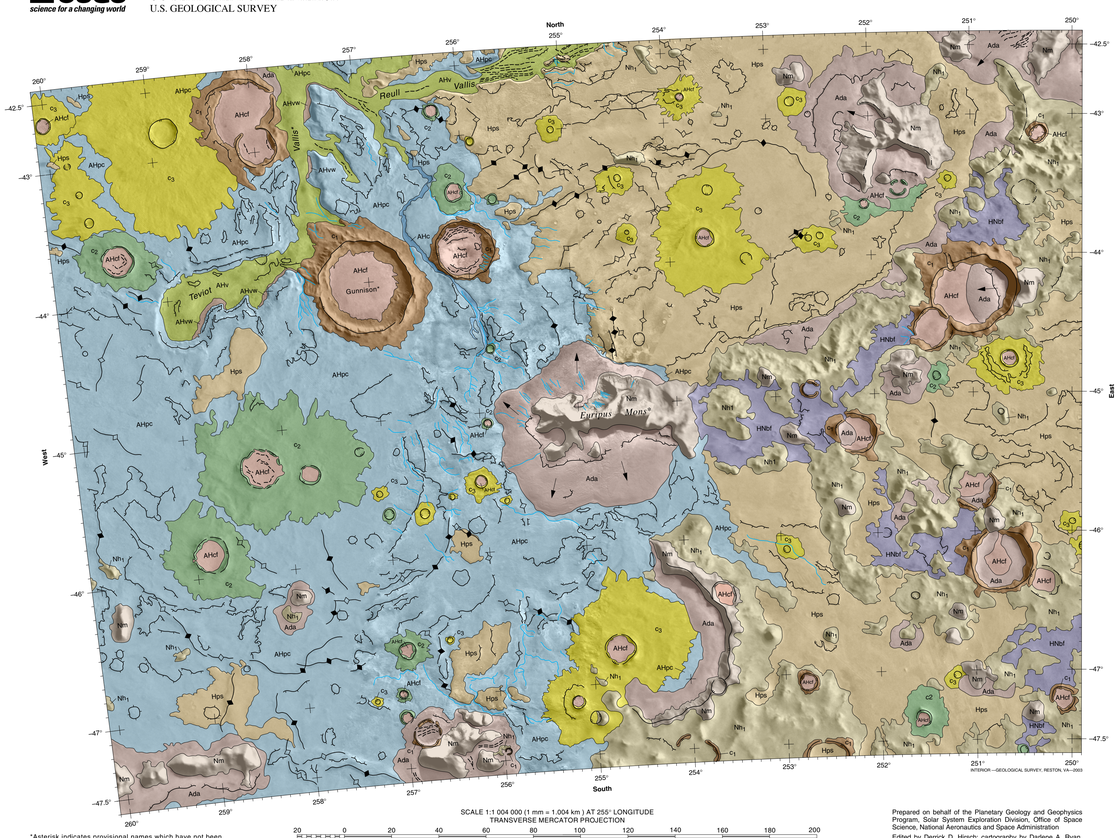

*Asterisk indicates provisional names which have not been approved by the International Astronomical Union.

Prepared on behalf of the Planetary Geology and Geophysics Program, Solar System Exploration Division, Office of Space Science, National Aeronautics and Space Administration

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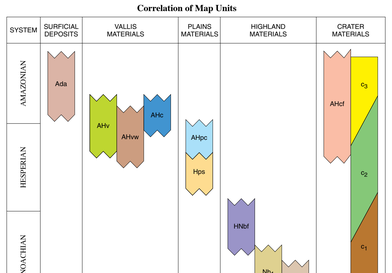
Manuscript approved for publication January 28, 2002

Correlation of Map Units



DESCRIPTION OF MAP UNITS

[Unit descriptions and interpretations are based on morphology, texture, albedo, and stratigraphic position as observed in Viking Orbiter images]

SURFICIAL DEPOSITS

Ada **Debris apron material**—Deposits having smooth, relatively featureless (in low- to medium-resolution images, >90 m/pixel) surfaces with lobate fronts; may exhibit pits and (or) lineations; borders highland massifs, crater rims, and valls walls. *Type areas*: 44.3° S., 250.9° W. (smooth), 45.5° S., 255° W. (pitted), and 44.9° S., 255.3° W. (lineated). *Interpretation*: Deposits of unconsolidated material resulting from mass wasting of rugged highland massifs, crater rims, and valls walls; mobility possibly due to incorporation of ice (for example, Squyres and Carr, 1986; Crown and others, 1992); pits may be from partial collapse of volatile-rich debris; ridges transverse to apparent flow direction due to compressional deformation; gullies parallel to apparent flow direction indicate fluvial erosion of debris apron surfaces at probable lobe boundaries

VALLIS MATERIALS

AHv **Vallis floor material**—Deposits forming floor of Reull and Teviot* Valles; lineated parallel to vallis walls or smooth. *Type areas*: 42.5° S., 255.3° W. (lineated), 44° S., 259° W. (smooth). *Interpretation*: Sedimentary material derived from surrounding units emplaced by a combination of collapse and flow; modified by small-scale deflation and fluvial redistribution; lineations may be related to flow of water and (or) debris through the canyon and (or) due to coalescence of debris aprons (Squyres, 1978); may also include an eolian mantle

AHvw **Vallis wall material**—Smooth deposits occurring at base of walls of Reull and Teviot* Valles; typically overlain by vallis floor material. *Type area*: 43.25° S., 257.5° W. *Interpretation*: Materials eroded from highland and plains units deposited at the base of vallis walls

AHc **Channel material**—Smooth to pitted deposit that fills tributary of Reull Vallis. *Type area*: 43.8° S., 256.5° W. *Interpretation*: Sedimentary materials eroded from surrounding plains and deposited by water flowing through channel

PLAINS MATERIALS

AHpc **Channeled plains material**—Smooth to irregular surfaces characterized by sinuous channels and numerous scarps; contains scarp-bounded mesas of smooth plains unit; fluted where exposed along Reull Vallis; exhibits ridges with subdued morphologies and degraded, subdued, and infilled craters adjacent to Reull Vallis. *Type area*: 45° S., 256.5° W. *Interpretation*: Material deposited following erosion of surrounding highland and plains materials; sediments subsequently eroded and redistributed to form smooth and scoured (irregular) surfaces. Presence of channels and scarps, and degraded or subdued nature of ridges and craters due to fluvial erosion and redistribution of material within the unit, possibly related to flooding from Reull Vallis. Mapped as smooth plains material (unit Hps) by Price (1998) and previously mapped as channeled plains rim unit (unit AHhg) by Greeley and Guest (1987), Mest (1998), and Mest and Crown (2001)

Hps **Smooth plains material**—Consists of generally smooth, relatively featureless materials embaying highland units; exhibits some channels and scarps; some occurrences have lobate margins; appears pitted adjacent to Reull Vallis. Wrinkle ridges within unit have subdued morphologies. Also occurs as flat-topped, scarp-bounded mesas within channeled plains unit. Lightly cratered. *Type area*: 44.3° S., 254° W. *Interpretation*: Sedimentary deposits resulting from overflow of Reull Vallis; emplaced as sediment-rich flows and (or) from transient body of water; also may contain materials eroded from highland terrains; subdued morphology of wrinkle ridges due to erosion and burial by plains material. Mapped as mesa material (unit AHm) by Price (1998) and previously included within smooth plateau unit (unit Hpg) by Greeley and Guest (1987)

HIGHLAND MATERIALS

HNbf **Intermontane basin fill**—Smooth to slightly hummocky deposits filling low-lying regions within highlands. Some occurrences have scarp-bounded edges; some exposures contain channels. *Type area*: 43.8° S., 251° W. *Interpretation*: Sedimentary deposits derived from highland materials; may also contain eolian deposits with non-local sources; some deposits eroded by fluvial processes forming channels

NH_1 **Basin-rim unit**—Material of Hellas basin rim; consists of rugged, mountainous terrains with small sections of smooth deposits; dissected by channels which may extend onto younger materials; typically embayed by younger plains; some exposures contain talus deposits; heavily cratered. *Type area*: 44.75° S., 252.5° W. *Interpretation*: Impact-generated unit of ancient martian crust modified by fluvial and eolian processes (Greeley and Guest, 1987); may contain mantling deposits derived from local or wind-blown materials; channel formation due to combination of ground water sapping and runoff

Nm **Mountainous material**—Occurs throughout mapped area. Forms small to large, rugged, isolated massifs within basin rim unit and younger units; typically embayed by younger plains; some surrounded by debris aprons. *Type area*: 45° S., 254.4° W. *Interpretation*: Ancient crustal material uplifted during formation of impact basins (Greeley and Guest, 1987)

CRATER MATERIALS

[Impact craters with rim diameters <4 km not mapped]

AHcf **Crater fill material**—Forms smooth or pitted surfaces on crater floors; some deposits display lobate margins against interior crater walls. *Type areas*: 44° S., 257° W. (smooth) and 44.3° S., 251.2° W. (pitted). *Interpretation*: Fluvial and (or) eolian sedimentary deposits and (or) coalesced debris aprons from crater rim materials that accumulate on crater floors; pitting may be due to partially collapsed volatile-rich materials

c_3 **Well-preserved crater material**—Characterized by pronounced, continuous crater rim elevated relative to surrounding materials and by well-defined, continuous ejecta blanket. *Interpretation*: Pristine crater material exhibiting little degradation; some crater floors may contain deposits emplaced by mass wasting, eolian activity, and (or) fluvial processes

c_2 **Moderately degraded crater material**—Characterized by a crater rim that may exhibit only minor relief above surrounding materials and by discontinuous, poorly exposed ejecta. *Interpretation*: Impact craters with moderate degree of degradation; most crater floors contain deposits emplaced by mass wasting, eolian activity, and (or) fluvial processes

c_1 **Highly degraded crater material**—Characterized by a degraded crater rim that may be discontinuous and exhibits little relief relative to the surrounding materials; no ejecta and smooth, featureless crater floors. *Interpretation*: Highly degraded impact crater material. Ejecta has been completely eroded or mantled by younger materials; crater floors have been modified by erosion. Most crater floors contain deposits emplaced by mass wasting, eolian activity, and (or) fluvial processes

Contact—Dashed where approximately located or gradational

Ridge

Subdued ridge

Lineament

Scarp—Dashed where inferred

Channel

Crater rim crest

Degraded crater rim crest

Apparent flow direction

INTRODUCTION

Mars Transverse Mercator (MTM) quadrangles –45252 and –45257 (latitude 42.5° S. to 47.5° S., longitude 250° W. to 260° W.) cover a portion of the highlands of Promethei Terra east of Hellas basin (fig. 1). The map area consists of scarps of cratered ancient highland materials having moderate to high relief, isolated knobs and massifs of rugged mountains material, and extensive tracts of smooth and channeled plains. Part of the ~1,500-km-long Reull Vallis outflow system (fig. 2) is within the map area. The area also contains surficial deposits, such as the prominent large debris aprons that commonly surround highland massifs. Regional slopes are to the west, toward the Hellas basin, as indicated by topographic maps of Mars (U.S. Geological Survey, 1989; Smith and others, 1999). Approximately 60% of the surface of Mars is covered by rugged, heavily cratered terrains believed to represent the effects of heavy bombardment in the inner solar system ~4.0 billion years ago (Murray and others, 1971; Schubert and others, 1992; Tanaka and others, 1992). Much of this terrain, including that within the map area, records a long history of modification by tectonism, fluvial processes, mass wasting, and eolian activity. The presence of fluvial features to the east of Hellas basin, including Reull Vallis and other smaller valleys, channels, has significant implications for past environmental conditions. The degraded terrains surrounding Hellas basin provide constraints on the role and timing of volatile-driven activity in the evolution of the highlands. Current photogeologic mapping at 1:500,000 scale (see also Mest and Crown, 2002) from analysis of Viking Orbiter images complements previous geomorphic studies of Reull Vallis and other highland outflow systems, drainage networks, and highland debris aprons, as well as regional geologic mapping studies and geologic mapping of Hellas basin as a whole at 1:5,000,000 scale (Crown and others, 1992; Mest and Crown, 1998; Mest and Crown, 2001; Pierce, 2001; Leonard and Tanaka, 2001). Viking Orbiter image coverage of the map area generally ranges from 160 to 220 m/pixel; the central part of the map area is covered by higher resolution images (~47 m/pixel). Crater size-frequency distributions have been compiled to constrain the relative ages of geologic units and determine the timing and duration of inferred geologic processes.

REGIONAL GEOLOGY

The highlands surrounding Hellas basin include Noachian materials that are believed to represent the oldest rocks on Mars (Murray and others, 1971; Tanaka, 1986; Tanaka and others, 1988, 1992). Erosion of highland materials began during the Late Noachian Epoch and continued throughout the Hesperian, resulting in deposition of extensive plains materials in and around Hellas basin (Greeley and Guest, 1987; Leonard and Tanaka, 2001). The geologic units of Hellas basin and its rim were initially grouped into the Hellas assemblage, which consists of rugged highland plateaus and massifs dissected by channels and valley networks, and various younger plains units, some of which contain channels, ridges, scarps, and mesas (Greeley and Guest, 1987). Later mapping further subdivided the units according to geographic setting and stratigraphic relations (Leonard and Tanaka, 2001).

Volcanism in the Hellas region occurred north and northwest of the map area in the Late Noachian/Early Hesperian Epochs with formation of Hadriaca and Tyrrhena Paterae (for example, Plescia and Saunders, 1979; Greeley and Crown, 1990; Crown and others, 1992; Crown and Greeley, 1993; Tanaka and Leonard, 1995; Gregg and others, 1998). The ridged plains material of Hesperia Planum, the stratigraphic base of the Hesperian System (Tanaka, 1986; Greeley and Guest, 1987), is to the northeast. The highland paterae are interpreted to consist of pyroclastic deposits, possibly resulting from phreatomagmatic eruptions (Greeley and Spudis, 1981; Greeley and Crown, 1990; Crown and Greeley, 1993). The presence of lava flow lobes within an ~1000-km-long flow field extending from Tyrrhena Patera and a smooth deposit infilling the caldera of Hadriaca Patera suggest some effusive activity occurred late in the volcanoes' histories (presumably Late Hesperian/Early Amazonian; Crown and others, 1992; Gregg and others, 1998). The ridged plains material of Hesperia Planum is considered to be one of many areally extensive volcanic plains-forming units found on the surface of Mars (Scott and Tanaka, 1986; Greeley and Guest, 1987). Ridged plains material exhibits mare-type wrinkle ridges, may contain lobate scarps (possibly flow fronts), and is generally interpreted to be composed of flood lavas that fill low-lying areas (Potter, 1976; King, 1978; Greeley and Spudis, 1981; Scott and Tanaka, 1986; Greeley and Guest, 1987).

MTM –45252 and –45257 quadrangles exhibit a series of landforms that provide evidence for fluvial activity (see "Fluvial Features"), which is characteristic of martian highland surfaces. Several widespread plains units east and northeast of Hellas basin suggest that extensive resurfacing occurred in low-lying regions within the highlands. These plains units subsequently were eroded in the Late Hesperian/Early Amazonian Epochs (Greeley and Guest, 1987). Also during the Hesperian Period the highland outflow channels (Reull, Teviot,* Dao, Niger, and Harmakhis Valles) formed, depositing significant amounts of eroded material on their floors, along their banks, and on the floor of Hellas basin. Recent studies of the mid-Hesperian/Early Amazonian-aged outflow channels in the eastern Hellas region suggest an origin by subsurface flow and collapse of plains materials combined with fluvial processes, followed by modification by wall retreat (Crown and others, 1992; Tanaka and Leonard, 1995; Mest and Crown, 2001, 2002). Each outflow channel heads within or adjacent to a volcanic feature: Dao Vallis cuts into the flank materials of Hadriaca Patera, Niger and Harmakhis Valles are adjacent to the Tyrrhena Patera lava flow field, and Reull Vallis begins in Hesperia Planum (fig. 2). The fact that the outflow channels are in close proximity to these volcanic features suggests channel formation may be in part due to mobilization and release of subsurface volatiles by volcanic heat (Squyres and others, 1987; Crown and others, 1992). In addition, debris aprons that extend from highland massifs, interior crater walls, and vallis walls are observed; mass-wasting appears to have been a significant process in the most recent geologic history of the region (Crown and others, 1992, 1997; Crown and Stewart, 1995; Tanaka and Leonard, 1995; Crown and Mest, 1997; Stewart and Crown, 1997; Mest and Crown, 2001; Pierce, 2001).

STRATIGRAPHY

Relative ages of geologic units mapped in MTM –45252 and –45257 quadrangles were determined using stratigraphic relations in combination with crater size-frequency distributions compiled in a regional study of the Reull Vallis region (table 1; Mest, 1998; Mest and Crown, 2001). Craters were counted on a Mars Digital Image Mosaic (231 m/pixel; latitude 27.5° S. to 47.5° S., longitude 245° W. to 265° W.). With few exceptions (discussed below), crater size-frequency distributions show relative ages consistent with previous studies (for example, Greeley and Guest, 1987; Crown and others, 1992; Tanaka and Leonard, 1995; Leonard and Tanaka, 2001).

The oldest materials exposed in the area comprise the basin-rim unit (unit NH_1) and mountainous material (unit Nm; fig. 3). Mountainous material forms large rugged blocks believed to be ancient crustal materials uplifted during impact basin formation (fig. 4; Scott and Tanaka, 1986; Greeley and Guest, 1987). Mountainous material forms rugged, isolated or clustered massifs found within the basin-rim unit or embayed by younger plains materials. Numerous massifs of mountainous material in the area are surrounded by debris aprons, interpreted to consist of unconsolidated material eroded from highland terrains (Crown and others, 1992; Crown and Stewart, 1995; Stewart and Crown, 1997; Pierce, 2001).

The basin-rim unit (unit NH_1), previously mapped by Greeley and Guest (1987), is interpreted to consist of ancient crustal materials (impact breccias and volcanics) uplifted during impact basin formation. In places, the basin-rim unit also may include mantling deposits derived from local materials or eolian deposits. The basin-rim unit forms most of the rugged, mountainous terrain of Promethei Terra. Exposures of this unit, especially north of the map area (latitude 37.5° S. to 42.7° S., longitude 250° W. to 260° W.), appear more eroded than other highland materials and tend to be incised with small valleys, most of which terminate at the contacts of younger sedimentary deposits. The presence of such valleys provides evidence for erosion of highland materials and subsequent deposition early in the region's history.

Intermontane regions within the basin-rim unit appear to have smooth surfaces, similar to those in MTM –40252 and –40257 quadrangles (Mest and Crown, 2002). These areas are filled with a smooth unit, called intermontane basin fill (unit HNbf), which has been eroded by channels and valley networks. Lack of high-resolution coverage of highland materials within the map area makes characterization of this and other highland material difficult. Nevertheless, the stratigraphic position of the basin-rim unit relative to that of intermontane basin fill north of the map area (Mest and Crown, 2002). Exposures of intermontane basin fill in the map area contain scarps and a few small channels (fig. 3). The presence of intermontane basin fill among highland materials indicates that significant sedimentation and subsequent deposition in the older parts of the map area. The lack of well-developed valley networks within these exposures of intermontane basin fill suggests that (1) low-resolution coverage prevents them from being observed, (2) networks and channels have been modified or destroyed, and (or) (3) these materials were not subjected to the same degree of fluvial erosion as were those north of the map area.

The basin-rim unit (NH_1) and mountainous material (unit Nm) are the oldest materials exposed in the map area (Middle Noachian to Early Hesperian). However, crater size-frequency distributions compiled by Mest (1998) and Mest and Crown (2001) show ages slightly younger than other studies, which indicate formation in the Early Noachian Epoch (Greeley and Guest, 1987; Crown and others, 1992). The degradational history and the small areal extents of these units may account for these younger ages. Furthermore, intermontane basin fill (unit HNbf), included as part of the basin-rim unit in the regional studies of Mest (1998) and Mest and Crown (2001), most likely would have buried small- and medium-sized craters giving the basin-rim unit in the map area a younger age than expected. The basin-rim unit and mountainous material in the map area are most likely Middle Noachian in age, although regionally the units began forming in the Early Noachian. Although crater statistics were not compiled for intermontane basin fill, superposition relationships show that it is younger than the basin-rim unit and older than smooth plains material (unit Hps), suggesting a Late Noachian to Early Hesperian age.

MTM –45252 quadrangle is dominated by smooth plains material (unit Hps), with the largest exposures in the northern part of the map area; smaller isolated outcrops are found in southern MTM –45252 and as mesas within channeled plains material (unit AHpc) in MTM –45257. Both within and north of the map area, smooth plains material appears to embay Noachian highland materials (units NH_1 and Nm) and exhibits lobate terminations in some areas where the plains meet the highlands (fig. 3; Mest and Crown, 2001, 2002). At moderate resolutions (~90 m/pixel), smooth plains material displays relatively featureless surfaces, although irregular scarps, small valleys, and wrinkle ridges having subdued morphologies are evident. Closer examination reveals small (<4 km diameter) pedestal craters in the plains that appear to have excavated dark material, possibly representing a deposit underlying the smooth plains. At higher resolutions (~47 m/pixel), portions of smooth plains material adjacent to Reull Vallis contain pits or small-scale undulations (fig. 5). This surface texture could have resulted from minor erosion (scouring) of the plains as water drained from the area, localized collapse, and (or) mantling by wind-blown material forming dunes. Low-relief scarps and small channels within smooth plains material further suggest fluvial erosion after plains emplacement. A scarp several hundreds of kilometers in length, as well as numerous smaller scarps, are found south of Reull Vallis in the northern and central parts of MTM –45252 (fig. 3). These scarps face away from Reull Vallis, which suggests they are the edges of mudflow deposits emplaced from Reull Vallis and (or) the edges of a flood deposit that has been eroded by fluvial and eolian activity following its emplacement. These scarps are similar to scarps observed near Reull Vallis in MTM –40252 quadrangle (Mest and Crown, 2002). Smooth plains material is interpreted to be sediments deposited as a result of overflow of Reull Vallis, perhaps in a transient body of water, and (or) eroded from the surrounding highlands.

Flat-topped, scarp-bounded mesas found within channeled plains material (unit AHpc; Crown and others, 1992; Mest and Crown, 2002) south of Reull Vallis (fig. 6) have characteristics similar to smooth plains material. Their surfaces have a smooth texture and their bounding scarps are fluted and have similar erosional characteristics as smooth plains material (unit Hps) adjacent to Reull Vallis. These mesas are mapped as smooth plains material, which suggests the smooth plains extended farther south and west of Reull Vallis.

The erosional character of the edge of smooth plains material appears to change where exposed along the walls of Reull Vallis (see figure 2 and "Fluvial Features" for a complete description of Reull Vallis). Along a portion of Reull Vallis (northeast of MTM –45252), smooth plains material shows a fluted scarp boundary and appears to have been laterally eroded. However, in MTM –45252, along the lower part of segment 2 (fig. 5), smooth plains material shows no evidence of lateral erosion and extends to the canyon wall. In other locations, the edge of the smooth plains appears as a fluted scarp, such as where the lower part of segment 2 meets segment 3 and at the contact between channeled and smooth plains materials. Smooth plains material exposed north of segment 3, and mesas south of Reull Vallis, also have a fluted appearance (fig. 6). The variable nature of smooth plains material may provide evidence for its formation. Floodwaters from Reull Vallis may have resulted in emplacement of smooth plains material adjacent to the canyon; as the water receded, lateral erosion of smooth plains material occurred along the upper part of segment 2. A thicker, laterally extensive sequence of material may have been deposited adjacent to the lower part of segment 2 as a result of ponding floodwaters or blockage farther downstream. Subsequent release(s) of water, forming Teviot Vallis* (44.0° S., 258.6° W.) and enlarging segment 3 of Reull Vallis, also eroded smooth and channeled plains materials north and south of segment 3.

Smooth plains material also occurs as isolated patches within highland terrains in the southeastern part of the map area, separated from Reull Vallis by channeled plains unit and massifs of mountainous material (fig. 3). These isolated exposures of smooth plains material may have formed differently than those immediately adjacent to Reull Vallis, and possibly consist of sediments eroded from the highlands and deposited in adjacent low-lying areas. A component of eroded highland material also may be included in the smooth plains material near Reull Vallis.

Crater size-frequency distributions show that smooth plains material (unit Hps) may be Late Noachian to Late Hesperian in age. Smooth plains material in the map area was previously mapped as the smooth unit of the plateau sequence (unit Hpg) by Greeley and Guest (1987), which is Early Hesperian in age. Superposition relationships between smooth (unit Hps) and channeled plains (unit AHpc) materials, and cross-cutting relationships between smooth plains material and Reull Vallis indicate smooth plains material is most likely Early Hesperian in age.

The channeled plains rim unit (unit AHhg) consists of ridged plains material (unit AHpc) and smooth plains material (unit Hps—as discussed above). Portions of the channeled plains rim unit were subdivided into hummocky plains material (unit HNh), smooth plains material (unit AHps), and mesa material (unit AHm) by Price (1998), while retaining the channeled plains rim unit near the Hellas basin and adjacent to Dao, Harmakhis, and the terminus of Reull Valles (west of the current map area). In the current study, channeled plains material (unit AHpc) and smooth plains material (unit Hps) correspond to Price's (1998) smooth plains material (unit AHps) and mesa material (unit AHm), respectively.

An extensive exposure of channeled plains material occurs in MTM –45257 and continues into the western part of MTM –45252. In this area, channeled plains material has an irregular surface dissected by sinuous channels and scarps (figs. 3, 5). The surface of the channeled plains varies spatially across the unit, with localized areas of scoured and channeled terrain (44.5° S., 256° W.; west of map area at 42° S., 264° W.) distinct from smoother regions with fewer channels in less regular patterns (for example, adjacent to Teviot Vallis*). The edge of channeled plains material is fluted where exposed in Teviot Vallis* displaying at least two laterally continuous layers (fig. 6). Channeled plains material also contains ridges displaying pristine and degraded morphologies, as well as several large (>15 km diameter) infilled craters (fig. 7). These craters have slightly degraded rims and the surfaces of their ejecta blankets appear subdued though they display well-defined lobate margins. Most of these craters appear to be filled almost to their rims with materials similar to smooth plains material. Smaller craters display distinct rampart morphologies, and similar to some small craters in nearby smooth plains material, channeled plains material contains small (<4 km diameter) pedestal craters with ejecta blankets composed of darker material, indicating these impacts may be excavating a deposit from beneath the channeled plains.

Superposition relationships and crater densities for the channeled plains rim unit in Mest (1998) and Mest and Crown (2001) constrain the stratigraphic position of channeled plains material (unit AHpc) in this study. The N(2) and N(5) crater densities suggest formation during the Late Hesperian to Early Amazonian Epochs, consistent with ages determined by Greeley and Guest (1987) and Crown and others (1992). Channeled plains material is interpreted to be a sedimentary unit deposited following removal of smooth plains material to the southwest of Reull Vallis. Channeled plains material most likely consists of sediments eroded from the smooth plains and sediments transported in the floodwaters associated with Reull Vallis. Large volumes of water may have been released during the formation of Teviot Vallis.* Due to regional differences in topography across the channeled plains, some of the water flowed toward Hellas basin and some drained back into Reull Vallis. Channels west of the map area are oriented radially to Hellas, whereas channels south of Reull Vallis are perpendicular to the vallis. The floodwaters eroded smooth plains material south of Reull Vallis, leaving mesas of smooth plains and exhuming partially buried impact craters and ridges. A large crater west of the map area (41.5° S., 263.5° W.; ~120 km diameter) remains almost completely buried with only a few pieces of its rim exposed at the surface (Price, 1998). The surface of the channeled plains subsequently was scoured and sediments were redistributed by the receding floodwaters forming localized areas of scoured and channeled terrain and areas of smoother, less-channeled deposits. In addition, more recent eolian processes could have deposited dust within the channeled plains, thus contributing to the subdued appearance of ejecta blankets and wrinkle ridges (Leonard and Tanaka, 2001).

Within the channeled plains occurs an ~125-km-long tributary (44° S., 256.2° W.) to Reull Vallis. Channel floor material (unit AHc) covers the tributary's floor and is believed to consist of unconsolidated debris deposited from the channel's bedload, as well as a component of eolian deposits. This unit is not represented well in Viking Orbiter images, however in Mars Orbiter Camera (MOC) image M04-00726 (fig. 8), the unit displays a mostly smooth surface with irregularities caused by scarps and possibly small dunes. Based on its presence within the channeled plains and its intersection with Reull Vallis, the channel floor material is presumably similar in age to that of vallis floor material (Late Hesperian to Early Amazonian as discussed below).

The deposits forming the floor of Reull and Teviot* Valles, vallis floor material (unit AHv), display smooth and hummocky to lineated surfaces in the portions of the canyons in the map area. In the lower part of segment 2 (MTM –45252 and –45257 quadrangles) the surface of vallis floor material exhibits lineations that parallel the canyon walls (fig. 5). These lineations resemble those seen on lineated valley fill and are interpreted to have formed as interstitial ice caused unconsolidated materials to undergo shear during motion (Squyres, 1978, 1979; Squyres and Carr, 1986), similar to flow in terrestrial rock glaciers (Wahrhaftig and Cox, 1959). Collapse features or slump blocks also occur along the southern wall of Reull Vallis (fig. 5). Vallis floor material in segment 3 (MTM –45257) appears hummocky in Viking Orbiter images (fig. 6). Debris aprons seen along the walls of Reull Vallis in segment 3 within and north of the map area suggest some component of vallis floor material consists of debris shed from the canyon walls. Vallis floor material within Teviot Vallis* contains scarps and scarp-bounded mounds that suggest material may have been eroded and redistributed by fluvial activity. Vallis floor material is interpreted to consist of unconsolidated material infilling the valles emplaced by a combination of fluvial deposition and mass wasting. This reasonably explains the morphology of vallis floor material observed within the map area, although eolian modification may have occurred as well. Vallis wall material (unit AHvw) occurs along the base of the walls of Reull and Teviot* Valles (fig. 6); these deposits are apparently overlain in places by vallis floor material. Vallis wall deposits are interpreted to consist of materials shed from adjacent highland and plains units deposited at the base of the canyon walls and are similar to talus or colluvial deposits.

Few craters are observed within vallis floor material (unit AHv); previous studies have shown these deposits to be Late Hesperian (Greeley and Guest, 1987) to Early Amazonian in age (Crown and others, 1992). Crater statistics compiled in the regional studies by Mest (1998) and Mest and Crown (2001) showed Early Hesperian to Early Amazonian ages for vallis floor material in Reull, Dao, Niger, and Harmakhis Valles. However, this range can be limited to Late Hesperian to Early Amazonian by stratigraphic relationships between vallis floor and smooth plains materials. The older ages determined for these deposits are most likely due to the inclusion of the entire extent of Reull Vallis; the study by Crown and others (1992) examined only a portion of segment 3 of Reull Vallis near its terminus. If individual segments of Reull Vallis are considered separately, differences in age are evident (Mest and Crown, 2001). Vallis floor material in the upper part of segment 2 contains more craters than either the lower part of segment 2 or segment 3 of Reull Vallis. This suggests that the upper part of segment 2 could have a floor that is older than those of the other segments (Lower Hesperian versus Upper Hesperian to Lower Amazonian). This is presumably because it has not been affected by wall collapse and infilling to the same degree as the lower part of segment 2 and segment 3. Based on the crater statistics, this suggests that formation of Reull Vallis began in the Lower Hesperian and that it is an older system than Dao, Niger, and Harmakhis Valles. Crater counts for vallis wall material (unit AHvw) in Reull Vallis were not compiled in the regional study (Mest, 1998; Mest and Crown, 2001) due to their limited exposure, but this unit is believed to be Late Hesperian to Early Amazonian in age based on superposition relationships with vallis floor material. The correlation chart shows considerable overlap in the ages of valls wall and vallis floor materials—where their contact is clearly observed, vallis floor material is younger, and where unclear, the deposits of valls wall material may be younger or the deposits may be contemporaneous.

Numerous craters in the map area contain floor deposits that are mapped as crater fill material (unit AHcf), suggesting they have been infilled (figs. 3–7). This material varies morphologically among craters, which indicates crater fill material may have different origins. Crater fill material observed in some craters presumably consists of materials eroded from the crater walls by fluvial processes and deposited on the crater floor (44.3° S., 251° W.). Crater fill material in other craters has lobate margins and surfaces similar in morphology to debris aprons (42.8° S., 258.1° W.), and may be composed of volatile-rich debris shed from crater rims. Other occurrences of crater fill may consist of material deposited from external sources, similar to intermontane basin fill or smooth plains material (45.2° S., 258.2° W.). Finally, some crater fill material could be composed of eolian deposits.

Debris apron material (unit Ada) forms the youngest deposits in the map area and is observed extending from massifs of Noachian mountainous material (unit Nm; fig. 4), crater rims (fig. 3), and the walls of Reull Vallis. These debris aprons, and most aprons northeast of the Hellas basin, occur within a region extending from 30° to 47.5° S. and 245° to 270° W. (Crown and others, 1992; Crown and Stewart, 1995; Stewart and Crown, 1997; Mest, 1998; Mest and Crown, 2002; Pierce, 2001). Most debris aprons in the area are associated with mountainous material (unit Nm), commonly completely surround their parent massifs, spread laterally, and extend for distances up to ~40 km. Debris aprons around highland massifs have uniform or mottled albedos and sometimes exhibit lineations on their surfaces parallel and (or) perpendicular to the inferred direction of motion. Some massif-related aprons, especially the largest deposits, have lobate frontal morphologies and appear to be composed of multiple coalescing lobes (Crown and Stewart, 1995; Stewart and Crown, 1997). Debris aprons in craters and within Reull Vallis (Crown and Stewart, 1995; Stewart and Crown, 1997; Pierce, 2001) exhibit mottled albedos, relatively featureless surfaces, and arcuate to lobate fronts. Pitting is observed on the surfaces of massif-, crater-, and valls-related debris aprons, particularly those close to Reull Vallis. Debris aprons are interpreted to have formed by mass wasting of unconsolidated materials. Their surface morphology and the fact that these deposits have no preferred orientation and frequently completely surround their parent massifs indicate these deposits are derived locally and are not the result of regional eolian processes or fluvial activity (Crown and Stewart, 1995).

A large (~40 km long) debris apron surrounding Euripus Mons* (45.1° S., 255° W.; fig. 4) displays compressional ridges, a slump block, pitted surfaces, and multiple debris lobes. This debris apron also contains numerous channels and ridges on its surface, some of which appear to be at the junctions of individual flow lobes. These channels extend from a scarp-bounded depression to the apron's contact with the underlying plains material (Stewart and Crown, 1997). This depression is bounded by the parent massif and a massif-facing scarp and may indicate deflation of the apron near the massif as volatiles were released from the debris.

Interstitial ice within debris aprons may have promoted shearing of the materials, thus forming lineations parallel to the direction of flow (Squyres and Carr, 1986; Zimbelman and others, 1989; Crown and others, 1992) similar to that observed in lineated valley fill (Squyres, 1978, 1979). A common process at middle to high latitudes on Mars, this type of ice creep, also known as "terrain softening," tends to form concentric crater fill and debris aprons and flows (Squyres and Carr, 1986). Landforms produced by creep-related processes are common in the fretted terrain in the northern hemisphere (latitude 30° to 70°) where ice-rich materials appear to have flowed downslope (Squyres, 1978, 1979; Squyres and Carr, 1986). Here, valley floors contain lineated valley fill, characterized by lineations parallel to the valley walls, and debris aprons with lineations parallel to the apparent direction of flow, both indicating slow movement of volatile-rich debris (Squyres, 1978, 1979).

Few craters are observed within debris apron (unit Ada) and crater fill (unit AHcf) materials, of which exposures are not areally extensive. Crater size-frequency distributions of these materials suggest they are some of the youngest deposits in the map area, consistent with local stratigraphic relationships. Ages for debris apron material range from Late Hesperian to Middle Amazonian, and ages for crater fill material range from Late Hesperian to Early Amazonian. Crater fill material, found in craters superposed on units of various ages, is interpreted to have been formed by several different processes (for example, erosion of crater walls and rims, coalescence of debris aprons, and fluvial and eolian deposition). As observed in the regional study (Mest, 1998; Mest and Crown, 2001), craters are more abundant on the surfaces of crater fill material interpreted to have resulted from erosion of crater walls and rims than on crater fill material that appears to have formed by coalescing debris aprons or eolian deposits; thus a range of ages for crater fill material is expected.

Crater materials within the map area display various states of preservation, indicating degradation of these materials has been a continuing process throughout the evolution of the region. Well-preserved crater material (unit c_3) shows the least amount of degradation. This material is characterized by pronounced continuous crater rims that are elevated relative to the surrounding materials and by well-defined, continuous ejecta blankets. Many of these crater types display rampart morphologies, especially in the smaller craters. Moderately degraded crater material (unit c_2) is characterized by crater rims (sometimes discontinuous) exhibiting minor relief above the surrounding materials and by discontinuous and (or) poorly preserved ejecta blankets. Highly degraded crater material (unit c_1) shows the most degradation, with discontinuous crater rims exhibiting little to no relief above the surrounding materials and ejecta blankets that have either been completely eroded or mantled by younger materials. Many craters of all types (units c_3, c_2, and c_1) appear to have smooth, flat floors containing crater fill material (unit AHcf) with slight variations in albedo and characteristic morphologies. The fact that crater fill material may have various origins, and therefore ages, makes the presence (or lack) of this deposit an inappropriate method of characterizing crater ages within the map area.

FLUVIAL FEATURES

The geologic evolution of the map area appears to have been greatly affected by fluvial processes. Channels are observed within intermontane basin fill, and smooth plains, channeled plains, and debris apron materials. The presence of Reull and Teviot* Valles also indicates large volumes of water may have assisted in removing copious amounts of highland materials, depositing as well as eroding the surrounding plains materials.

CHANNELS

Channels in the map area consist of narrow troughs (<1 km wide) tens to hundreds of kilometers in length. Several small channels are visible within the smooth plains along its contact with the channeled plains in the north-central part of the map area (fig. 4). These channels dissect the scarp boundary of the smooth plains, which indicates some water flowed west from the smooth plains onto the channeled plains. Also, several poorly developed systems of channels are in the channeled plains just west of the smooth plains (figures 4 and 6—eastern MTM –45257). One example consists of a scarp-bounded valley that extends for several hundred kilometers within the channeled plains to the north toward Reull Vallis. The valley is generally flat-floored and featureless, but in places a small inner channel can be seen on its floor (fig. 8). Tributaries also enter this valley, which indicates water drained from the channeled plains into Reull Vallis. In addition, smaller channels and scarps are seen throughout the central part of the map area (45.5° S., 256.5° W.) and are oriented perpendicular to Reull Vallis, which suggests flow of water, at least locally, toward Reull Vallis. Channels and scarps observed west of MTM –45257 have a closely spaced parallel pattern and extend toward Hellas basin, consistent with the local topography (U.S. Geological Survey, 1989; Smith and others, 1999). The heavily scoured and channeled nature of the plains west of the map area suggest large quantities of water flowed over the surface toward Hellas basin. Local and regional differences in topography, and possibly subsurface structures, appear to have influenced the flow of water, and subsequently the locations of channels, across much of the eastern Hellas region.

REULL VALLIS

The Reull Vallis outflow system (fig. 2), nearly 1,500 km long, traverses the various geologic materials of Promethei Terra, displaying a complex morphology indicative of multiple styles and episodes of formation and modification (Crown and Mest, 1997; Mest and Crown 2001). Reull Vallis can be separated into three morphologically distinct segments. Segment 1 of Reull Vallis, in Hesperia Planum, contains streamlined islands and is oriented parallel to the prevailing (ancient northeast–southwest) winds through the highlands of Promethei Terra and is divided into a sinuous upper part having a v-shaped cross-sectional profile and a less sinuous, steep-walled lower part having a u-shaped cross-sectional profile (Mest and others, 1998). In segment 3, the main canyon alters its course northwestward through channeled and smooth plains materials and terminates near the source basin of Harmakhis Valles. The lower portions of segment 2 are in MTM –45252 and –45257, and part of segment 3 is in MTM –45257.