Abstracts of the Annual Planetary Geologic Mappers Meeting, 2001

June 17-20, 2001
Albuquerque, New Mexico

By Timothy Parker,[1] Kenneth Tanaka,[2] *and* David Senske,[3] *Editors*

With a section on

Field Trip to the Spring Deposits of the Western Rift and to the Very Large Array, New Mexico

By Larry Crumpler[4] *and* Jayne Aubele[4]

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Planetary Geologic Mappers Meeting 2001—Final Report

The annual Planetary Geologic Mappers Meeting serves two purposes. In addition to giving mappers the opportunity to exchange ideas, experiences, victories, and problems with others, presentations are reviewed by the Geologic Mapping Subcommittee (GeMS) to provide input to the Planetary Geology and Geophysics Mapping Program review panel's consideration of new proposals and progress reports that include mapping tasks. Funded mappers bring both oral presentation materials (slides or viewgraphs) and map products to post for review by GeMS and fellow mappers. Additionally, the annual meetings typically feature optional field trips offering earth analogs and parallels to planetary mapping problems.

The 2001 Mappers Meeting, June 18-19, was convened by Tim Parker, Dave Senske, and Ken Tanaka and was hosted by Larry Crumpler and Jayne Aubele of the New Mexico Museum of Natural History and Science in Albuquerque, New Mexico. Oral presentations were given in the Museum's Honeywell Auditorium, and maps were posted in the Sandia Room. In addition to active mappers, guests included local science teachers who had successfully competed for the right to attend and listen to the reports. It was a unique pleasure for mappers to have the opportunity to interact with and provide information to teachers responding so enthusiastically to the meeting presentation.

On Sunday, June 17, Larry and Jayne conducted an optional pre-meeting field trip. The flanks of Rio Grande Rift, east and west of Albuquerque and Valles Caldera north of town presented tectonic, volcanic, and sedimentary examples of the Rift and adjoining areas analogous to observed features on Mars and Venus. The arid but volcanically and tectonically active environment of New Mexico's rift valley enables focus on features that appear morphologically young and spectacular in satellite images and digital relief models. The theme of the trip was to see what, at orbiter resolution, "obvious" geologic features look like at lander (outcrop) scales. Trips to the top of the rift-flanking mountains (Sandia Peak, 10,600 ft) and the Valles Caldera, as well as various active spring deposits highlighted the day.

After welcoming remarks from the host, Larry Crumpler, opening remarks by Tim Parker and Dave Senske and a report on mapping program status by Ken Tanaka, the mappers' oral presentations began the morning of June 18, with a session on Venus Geologic Mapping. The afternoon continued with an exciting USGS Planetary GIS on the Web (PIGWAD) demonstration and ended with an open discussion of issues in planetary mapping. Posted maps of Venus quadrangles were viewed during the morning break.

Tuesday's Mars Geologic Mapping session began with a pep talk from Tim Parker encouraging mapping community input to the MER landing site selection committee and continued with Steve Saunders describing the potential contribution of Odyssey Mission data to the geologic mapping of Mars. A Mars map poster session was held during the morning break, and the meeting was adjourned mid-afternoon.

After the mappers meeting on Tuesday, attendants were treated to a

“Field trip to Mars.” The Institute of Meteoritics at the University of New Mexico houses an outstanding collection of meteorites, including those that have been identified as originating from Mars. The Institute tour featured examples of most of the different lithologies exhibited by martian meteorites identified to date, as well as some of the analytical tests (scanning electron microscope) they are conducting on specimens from ALH84001.

Wednesday, June 20, featured an optional post-meeting field trip to see a travertine quarry and nearby sites of travertine deposition, the Very Large Array near Socorro, and other volcanic features within the Rio Grande Rift.

Monday, June 18th:

8:30	Larry Crumpler, Welcome to Albuquerque!
9:00	Tim Parker and Dave Senske, Opening remarks
9:20	Ken Tanaka, Mapping Program Status
9:30	Venus Geologic Mapping
9:30	George McGill, V-8
10:10	Eric Grosfils, V-14
10:30	Break and Map Poster Session (All)
11:20	Jim Zimbelman, V-15, V-16
12:00	LUNCH (GEMS meeting during lunch)
1:30	Duncan Young, V-25
2:10	Les Bleamaster, V-35
2:50	Nathan Bridges, V-54
3:10	Mapping Tools
3:10	Trent Hare, USGS PIGWAD demonstration of new data and mapping tools
3:30	Discussion (All) Issues regarding all planetary mapping
5:00	Adjourn

Monday Evening: Open House at Larry Crumpler's

Tuesday, June 19th:

9:00	Tim Parker—Intro to Mars Session, and a Plea for mapping community input to MER landing site selection steering committee
9:20	Steve Saunders—Potential contribution of Odyssey Mission data to geologic mapping of Mars
9:40	Mars Geologic Mapping
10:00	Ken Herkenhoff, MTM 85200, 85080
10:20	Tim Parker/Brenda Franklin, MTM 45022, 45027, 50023, 50030
10:40	Break and Map Poster Session (All)
11:20	George McGill, MTM40012
11:40	Jim Zimbelman, MTM05142, 00142, 00147
12:00	LUNCH
1:30	David Crown/Scott Mest, MTM -20272, -25272, -35237, -40237, -45237 (+ status of Reull Vallis Mapping)
1:50	Ken Tanaka, Planum Australe
2:10	Jim Skinner/Ken Tanaka, NW Elysium/Utopia Mapping
2:30	Brian Hynek, Mapping of Terra Meridiani in support of MER
2:50	Larry Crumpler/Horton Newsom, Field Trip to Mars (UNM Institute of Meteoritics)
4:50	Meeting Adjourned

GEOLOGY OF BEREGHINYA PLANITIA QUADRANGLE (V-8), VENUS

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The Bereghinya Planitia quadrangle (V-8) lies between 25° and 50° N., 0° and 30° E. Bereghinya Planitia lies north of Eistla Regio, and quadrangle V-8 is immediately north of the Sappho Patera (V-20) quadrangle, which has been published (McGill, USGS map I-2637, 2000). A complete first draft of the geologic map of V-8 has been prepared digitally using Adobe Illustrator.

As expected, most of the plains units defined on V-20 continue northward into V-8. In particular, regional plains member b, which is areally dominant in V-20, also is areally dominant in V-8. Other plains units include regional plains member a, bright plains (lineated or fractured plains on some earlier maps), and reticulate plains, all believed to be older than regional plains member b; and dark plains, low-relief shield plains, and homogeneous plains, all believed to be younger than regional plains member b. All of these other plains units except reticulate plains are present in V-20 and defined for that quadrangle.

Lavas associated with shield fields, domes, and major channels are abundant in V-8; the shield field and dome flows are both older and younger than regional plains member b, whereas flows associated with major channels are entirely younger than regional plains member b. Flows associated with shield fields and channels surface a significant fraction of the total area of V-8.

Of particular interest in V-8 is the large number of coronae and corona-like features, most of which are sources of flows. There are at least 22 of these, 5 of which have been named by others (Audhumla, Beyla, Sulis, Onatah, and Vasadhara); the remaining 17 are provisionally identified with lower-case letters. In addition, others have named 4 paterae (Cavell, Sand, Trotula, and Yaroslavna) which appear to be indistinguishable from coronae. For the current draft of the map the paterae are mapped separately from the coronae, but it is likely that the 4 paterae will be renamed as coronae. Flows from these coronae and paterae cover a significant fraction of the quadrangle, and it is likely (but not provable) that much or perhaps even all of the materials of regional plains member b also were derived from these coronae and paterae. Almost all flows demonstrably derived from coronae and paterae are isolated from each other; that is, only locally are flows from two coronae or paterae in contact with each other. This creates significant problems for the determination of relative ages.

Most of the coronae in V-8 occur in one of two large belts. One of these is a large, north-concave arc in the northern part of the quadrangle that connects directly with the deformation belt Aušra Dorsa in the NE corner of the quadrangle. This suggests a genetic relation between coronae and deformation belts. The second and broader belt trends NNW across the east-central part of the quadrangle. This latter belt contains all 4 of the previously named paterae and 2 of the 5 previously named coronae.

Tessera terrane occurs as several small inliers within the plains. Regional plains member b is in contact with and younger than tessera in all of these inliers. Plains units that are definitely or probably older than regional plains member b (including regional plains member a, reticulate plains, and bright plains) are not in contact with tessera terrane and thus it is not possible to unequivocally establish relative ages.

The Bereghinya Planitia quadrangle includes all or parts of 22 impact craters, including most of the large crater Mona Lisa. In addition, there are several large dark-centered bright patches inferred to result from disintegration of bolides in the atmosphere before reaching the surface.

NEMESIS TESSERA QUADRANGLE (V14), VENUS

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Goals Investigation of the geological relationships preserved in the Nemesis Tessera quadrangle (25-50°N, 180-210°E), a mapping project initiated in June of 2001, is driven by four main science goals:

[1] Interpret the volcanic and tectonic history of two giant radiating fracture systems (dike swarms?) which formed in unusual geological settings—one is centered at the triple junction of a Y-shaped ridge belt while the focus of the other lies upon the rim of an odd fracture annulus [*Summer, 2001*];

[2] Evaluate whether systematic variations in the dominant style of volcanism occur within the region as a function of time [*Summer, 2002*], and use the altitude distribution of volcanic features interpreted to be reservoir-derived to test the hypothesis that their formation is controlled in part by neutral buoyancy [*Summer, 2001*];

[3] Characterize the origin and history of the regional stress fields by interpreting the distribution and relative timing of the diverse array of structural deformation preserved within the region [*Summer, 2002*];

[4] Integrate the stress field and volcanic history interpretations within this lowland area in order to assist with ongoing efforts to constrain competing regional/global resurfacing models and test the hypothesis that a global stratigraphic sequence exists on Venus [*Summer, 2003*].

Regional Setting The V14 quadrangle occupies the central portion of Ganiki Planitia, between the Beta-Atla-Themis volcanic zone and Atalanta Planitia, areas integrally linked to large scale mantle convection processes [e.g., 1-3]. The region immediately south of the quadrangle is dominated by Atla Regio, a major volcanic rise, while the area just to the north is occupied by the orderly system of compressional tectonic belts which characterize Vinmara Plantia. The V14 quadrangle thus lies between several key regions where mantle-related tectonic and volcanic activity has occurred, and careful analysis of the regional geology is expected to yield new insight into the relative timing of and interaction between these major, large scale, surface-shaping events.

Tectonic Features Structural deformation has produced tessera, ridge belts and rifts as well as a complex system of fractures and wrinkle ridges which extends throughout the region. Little is yet known about either the stratigraphy of these features or the sequence of stresses which produced them, but they are likely to record information about tectonic processes active both within and beyond the quadrangle's boundaries.

Volcanic Features Extensive, tectonically deformed volcanic plains characterize the quadrangle, which also contains at least 32 major volcanic centers identified during a global survey [4]. The latter include 2 calderas, 3 coronae, 6 large volcanoes, 10 shield fields and 11 arachnoids, but the details of their evolution and stratigraphic placement are not yet well constrained. At least one major volcanic center not identified during the global survey has already been recognized in the V14 quadrangle (one of the two radiating fracture systems), however, and other centers may exist—new FMAP-resolution studies elsewhere are identifying previously undetected volcanic centers at a variety of scales [e.g., 5]. In addition, it is unclear how many small volcanic features such as individual shields and localized fissure eruptions exist within the quadrangle, and thus the importance of this style of volcanism relative to the activity localized at the major centers remains poorly understood.

Summer, 2001 Mapping is proceeding using ESRI's ArcView software, and all FMAP framelets (Cycle 1) have been reprojected, mosaicked and integrated into this GIS system. I am currently mapping the two giant radiating fracture systems (Goal 1); with radii of 450 and >900 km these features, if they are dike swarms (rapidly emplaced, laterally extensive, discordant), may provide "tie points" which can be used to link together and interpret the regional stratigraphy. Four undergraduates are also working on the project this summer—one has chosen to focus on the neutral buoyancy question (Goal 2), one is studying the stress history recorded by a complex volcano-tectonic system near the center of the quadrangle (Goal 3), and two students are studying the development of shield fields within the region (Goal 2).

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MAPPING OF NEPTHYS MONS QUADRANGLE (V-54), VENUS N.T. Bridges, Jet Propulsion Laboratory (4800 Oak Grove Dr., MS 183-501, Pasadena, CA 91109; nathan.bridges@jpl.nasa.gov)

Introduction: Mapping of Nepthys Mons quadrangle (V-54, 300°-330° E., 25°-50° S.) has been proceeding for the last 15 months. Major research areas addressed are how the styles of volcanism and tectonism have changed with time, the evolution of shield volcanoes, the evolution of coronae, the characteristics of plains volcanism, and what these observations tell us about the general geologic history of Venus. Recent mapping has been significantly augmented by the use of pseudostereo anaglyphs that I have made from left and right pseudostereo pairs for Cycle 1 images. The advent of this great dataset has caused me to revise much of my mapping from what was presented at the last mappers meeting. I am currently awaiting Cycle 2 and Cycle 3 pseudostereo data, after which the complete quadrangle will be mapped in stereo. Because Cycle 1 covers the northwestern part of the quadrangle, greater confidence is placed in the mapping interpretations of this area. Therefore, this report and the presentation at the mappers meeting mainly covers this part of the quadrangle.

Reported here are several intriguing findings and a report on the use of the pseudostereo dataset.

Location and Major Geographic Features: The western part of the quadrangle, from its border at 300° E. to ~ 310° E., contains large coronae. Many of these structures are at the eastern termination of Parga Chasma, a broad zone of rifts and coronae striking ESE-WNW over a distance of nearly 8000 km. A large edifice, Tefnut Mons, intermediate in morphology between a classic shield volcano and corona, is also present. The eastern sector of the quadrangle, from ~320° E. to the border at 330° E., is marked by Dione Regio, a regional volcanic topographic rise ~2700 km N-S by 1200 km E-W [1]. The rise has been identified as a potential surface manifestation of mantle upwelling, where hotspots feed prodigious volcanism [2]. Unlike other highlands that have gravity anomalies of 150 mGal, the anomaly at Dione is small (20 mGal) and diffuse [1,3]. Dione Regio is similar to other rises on Venus, such as western Eistla and Bell, that lack large scale rift systems [4]. Dione Regio contains four large shield volcanoes (Ushas, Innini, Hathor, and Nepthys Montes) elevated 1.1-2.4 km above the adjacent plains. All are partially or wholly contained within the quadrangle. The area between Parga Chasma and Dione Regio, extending from ~310° E. to 320° E., lacks prominent coronae and large volcanoes. Rather, it is characterized by complex arrays of structures, many associated with Parga and Dione, and small-scale flows and edifices.

General Statigraphy and Structure: Tesserae, distributed as scattered inliers, appear to be the oldest unit and are truncated by tectonized plains which are, in turn, truncated by untextured plains. Stratigraphically above these regional plains units are scattered fields of shields and associated flows. Polygonal flows are common and appear to show a range of ages. Flows associated with coronae and shield volcanoes cap the sequence. In all cases, craters appear to be younger than adjacent units, consistent with other areas on Venus [6]. No craters are on the large shields. In all cases, attempts have been made to define the stratigraphy based on observed crosscutting relationships and to not map structures as units or define units by structures within them [7]. As of this writing, about 20 units, most of them plains units, have been identified, but these are still being defined as further mapping and incorporation of stereo data takes place.

Coronae Numerous coronae, some of which are transitional in morphology to shield volcanoes, occur within V-54 (figure 1). Temporal relationships between and among coronae are apparent in some cases. For example, radial fractures emanating from the coronalike volcano Tefnut Mons are clearly deflected around Bibi-Patma Corona to the south. This indicates that the Tefnut structures were influenced by the stress regime associated with the corona and therefore formed after Bibi-Patma. Many fractures and lineaments near the coronae are aligned along a similar strike to regional structures of Parga Chasma (~E-W), an association indicative of contemporaneous formation like that seen elsewhere on Venus [8-10]. In several cases, coronae radial fractures clearly cut ~E-W lineaments, indicating that coronae development probably post-dated regional tectonism associated with Parga.

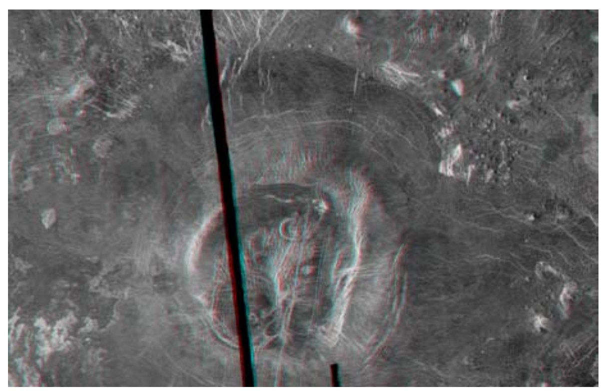

Figure 1. Pseudostereo anaglyph of Tunehakwe Corona in V-54.

Shield Plains: Plains with abundant small shields define at least three plains units ($ps_{1\text{-}3}$). Unlike relationships found in some areas of Venus that indicate a relatively old age for shield plains [11,12], those here are relatively young (figure 2). This is consistent with observations of other workers who find that shield plains can be stratigraphically young [13,14].

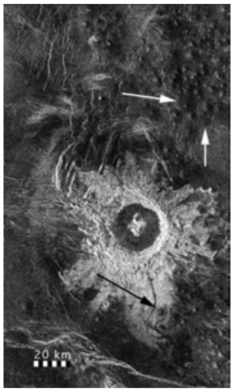

Figure 2a. Close-up of shield fields near von Paradis crater. Note that crater impact melt flows around one shield, indicating that the impact occurred after the shield formed (black arrow). Radar-dark flows associated with the shields truncate structural fabric on the adjacent plains, indicating that they are younger (white arrows).

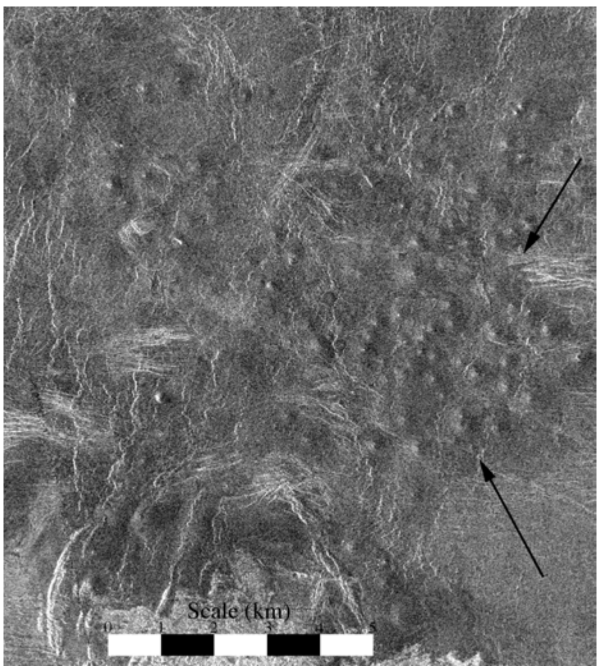

Figure 2b. Shield plains truncating structures on adjacent plains units (arrows), indicating that the shield plains are younger.

Polygonal Plains: Plains characterized by polygonal patterns (*pp*) are common and in many cases define a stratigraphic unit or series of units. Stratigraphic relationships indicate that some polygonal plains are sandwiched between other plains units (figure 3). This argues for the patterns being a lava flow cooling structure. This observation (although perhaps not pervasive over all of Venus) is at odds with interpretations by others that polygonal patterns on Venus are the result of temperature variations resulting from climate change [15-17].

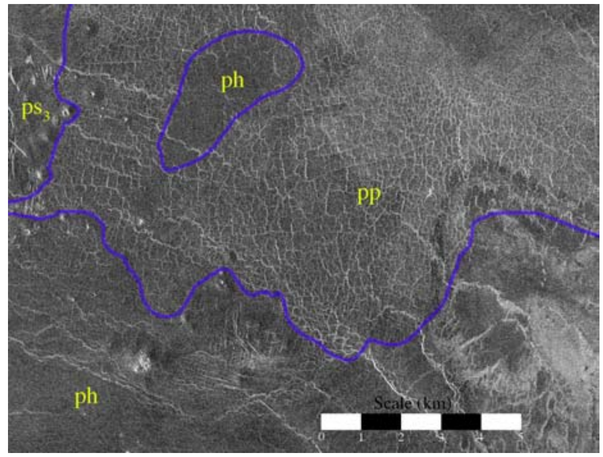

Figure 3 Contact relationships among homogeneous plains (*ph*), polygonal plains (*pp*), and member 3 of the shield plains (ps_3). Stratigraphic relationships elsewhere indicate that *ph* is older than *pp*, arguing that the polygons are lava flow cooling structures.

Use of Stereo Data: The use of pseudostereo anaglyphs has resulted in a virtual complete revision of previously mapped areas. For example, Tunehakwe Corona (Figure 1) shows prominent topography, much of which can be correlated to boundaries between lineated and non-lineated materials. An elevated corona annulus interior to an outer moat is apparent. Such 3-D information cannot easily be discerned from 2-D synthetic aperture radar images, nor is it easily interpretable from smaller-scale hardcopy pseudostereo pairs. This example, plus others that I will present, illustrate how stereo information has improved the mapping of V-54.

Conclusions Although a more complete understanding of the stratigraphy in V-54 must await the completion of mapping, two findings thus far have implications for venusian geology: (1) shield plains are a young unit, and (2) the stratigraphic relationships of polygonal plains are inconsistent with on origin induced by global temperature changes. The mapping of this quadrangle should be completed by the end of calendar year 2001, after which it will be submitted to USGS.

References: [1] Keddie, S.T. and J.W. Head (1995), JGR, 100, 11,729-11,754. [2] Smrekar, S.E. (1997), in, Venus II, U. Ariz. Press, 845-878. [3] Bindschadler, D.L. et al. (1992), JGR, 97, 13,495-13,352. [4] Stofan, E.R. et al. (1995), JGR, 100, 23,317-23,327. [6] Schaber, G.G. et al. (1992), JGR, 97, 13,257-13,301. [7] Hansen, V.L. (2000), Earth Plan. Sci. Lett., 176, 527-542. [8] Stofan, E.R. et al. (1992), JGR, 97, 13,347-13,378. [9] Baer, G. et al. (1994), JGR, 99, 8355-8369. [10] Hamilton, V.E. and E.R. Stofan (1996), Icarus, 121, 171-194. [11] Aubele, J.C. (1996), LPSC XXVII, 49-50. [12] Basilevsky, A.T. and J.W. Head (1998), JGR, 103, 8531-8544. [13] Addington, E.A. (1999), LPSC XXX, 1281. [14] Guest, J.E. and E.R. Stofan (1999), Icarus, 139, 55-66. [15] Bullock, M.A. and D.H. Grinspoon (1996), JGR, 101, 7521-7529. [16] Solomon, S.C. et al. (1999), Science, 286, 87-90. [17] Anderson, F.S. and S.E. Smrekar (1999), JGR, 104, 30,743-30,756.

GEOLOGIC MAPPING IN V-61 QUADRANGLE, VENUS: PRELIMINARY RESULTS. M. A. Ivanov[1] and J. W. Head[2]; [1]Vernadsky Institute, Acad. of Sci., Moscow, Russia; [2]Brown Univ., Providence, RI, USA. (james_head_iii@brown.edu)

Introduction: We have undertaken a reconnaissance mapping of the territory of V-61 Quadrangle. The territory of the quadrangle covers a transition zone between the southern portion of the basin of Lavinia Planitia and the northern portion of the Lada Terra upland. Our goals at this step of the mapping were: 1) to develop a sense of the general geologic themes of the area under study; 2) to see if the stratigraphic scheme we developed and used during the mapping of one adjacent, V-55 (Lavinia Planitia) [1,2], and two remote quadrangles, V-4 (Atalanta Planitia) and V-13 (Ganiki Planitia) is applicable to the transitional zone between lowlands and uplands, and 3) to establish the main relationships of units and structures in the area of the V-61 quadrangle.

Main geologic features of the area. The V-61 quadrangle covers the area from 50° to 75° S and from 300° to 360° E and spreads from the southern margins of Lavinia Planitia (N portion of the area) to Lada Terra (S portion of the area). [3] Vast regional plains, the surface of which is deformed by numerous wrinkle ridges, characterize a significant portion of the quadrangle. Sometimes, wrinkle ridges are collected into broad zones that are preferentially located in the western part of the quadrangle and oriented there generally in a N-S direction. Fragments of ridge belts are seen through the whole area of V-61. The belts make up local ridges which separate the surface of the regional basin into relatively small (a few hundreds of km across) second-order basins. The belts are oriented preferentially in a NE direction both in the western and eastern portions of the quadrangle (Morrigan Linea and Penardun Linea) but in the southern portion of the quadrangle the (Spidola Dorsa) ridge belt is oriented in a NW direction. Both Morrigan Linea and Penardun Linea are the southern continuations of the deformation belts featuring the central part of the Lavinia Planitia basin [4]. A prominent zone of fractures, Kalaipahoa Linea, crosses the central portion of the map area and runs from its western margin in a SW direction to Kamui-Huci Corona. The southeast corner of the quadrangle is dominated by the giant Quetzalpetlatl corona. Quetzalpetlatl is the source of vast lava flows radiating from the corona in W (Cavillaca Fluctus) and SW directions (Juturna Fluctus). Two additional centers of volcanic activity, Jord Corona and Tarbell Patera, are within the eastern portion of fracture zone of Kalaipahoa Linea. These centers appear to be the sources of the large volcanic flow, Mylitta Fluctus [5] flowing down into the lowland of Lavinia Planitia.

Stratigraphic units in the V-61 area. The surface in the V-61 area is composed of several units that appear similar to those mapped elsewhere [6-14] with one exception: There is no tessera terrain within the V-61 quadrangle. The area named Magu tessera is, actually, a fragment of a ridge belt. This is a NW trending branch of Morrigan Linea. The other units within the map area are as follow (from oldest to youngest). *Densely lineated plains (pdl).* The surface of this unit is heavily dissected by numerous densely packed narrow sub-parallel lineaments a few tens of km long and a few hundred meters (and down to the resolution limit) wide. The plains have relatively high radar backscatter cross-section. They form small (tens of km across) equidimensional and elongated fragments elevated relative to their surroundings and heavily embayed by younger lava plains. Kipukas of pdl occur within the central portion of Quetzalpetlatl corona and are arranged in a radial zone which is oriented in a N-S direction and runs radial to the north from the corona center. *Ridged and grooved plains (prg) and Ridge belts (rb).* These are materials with the morphology of lava plains occasionally deformed by broad ridges. The ridges are up to 10-15 km wide and up to several tens of km long. Where not ridged, the plains, prg, have a gently rolling and morphologically smooth surface. At some locations, the ridges are packed more densely and form belts, rb. Ridges of the belts gradually merge with the less deformed prg suggesting that the belts are tectonic facies of the same material unit. The radar backscatter cross-section of prg is higher than that of regional plains. There are no direct contacts between pdl and prg within the map area and their relative age cannot be established. Elsewhere on Venus (V-55, Lavinia Planitia; V-4, Atalanta Planitia; V-13, Ganiki Planitia), however, these two units are usually in contact and there is evidence there that prg is younger than pdl. Probably, this relative timing of prg and pdl is valid within V-61 quadrangle also. *Shield plains (psh)* are characterized by the presence of numerous small (from a few km up to 10 km across) shield-like features, interpreted as volcanic edifices. The surface of the plains is morphologically smooth, sometimes deformed by a few wrinkle ridges. Shield plains typically occur as small equidimensional areas several tens of km across. The radar backscatter cross-section of the plains is slightly higher than that of the surrounding regional plains and lower than the cross-section of the tectonized units. Material of the plains embays older units and there is evidence for the embayment of psh by material of the regional plains. In the area under study, shield plains mostly occur in the northern and western portions of the quadrangle in a spatial association with the ridge belt of Morrigan Linea. *Plains with wrinkle ridges lower member (pwr_1)* are characterized by morphologically smooth surfaces moderately deformed by numerous wrinkle ridges. The surface of the plains usually has uniform and relatively low radar backscatter cross-section. The homogeneous albedo pattern of pwr_1 without visible flow-like features precludes identification of the sources of the unit material. The unit makes up a significant portion of the surface within the quadrangle (about 50-55%). Material of the plains broadly embays all previous units. *Plains with wrinkle ridges, upper member (pwr_2)* are characterized by morphologically smooth surfaces moderately deformed by wrinkle ridges. The ridges appear to be of the same family of structures deforming pwr_1. The main difference between pwr_2 and pwr_1 is the distinctly higher albedo of pwr_2. The pwr_2 plains usually occur as equidimensional or slightly elongated flow-like patches tens to several hundreds of km long. Sharp boundaries between the two members of the regional plains are typical and there is evidence there for the embayment of pwr_1 by the material of pwr_2. The pwr_2 plains are concentrated in the SW corner of V-61 without clear spatial association with distinct volcanic sources. *Smooth plains (ps)* are characterized by morphologically smooth featureless surfaces which appear to be dark in the images. Smooth plains mostly occur in the western and central portions of the map area around crater Meitner and in local basins between branches of ridge belts. Material of the plains embays all the above units and is deformed by a few narrow fractures and by graben of Kalaipahoa Linea. *Lobate plains (pl)* consisting of a great number of morphologically smooth radar bright and dark flows is one of the most abundant units within the map area. Lobate plains are concentrated in the eastern portion of the quadrangle and occur in close spatial association with distinct sources such as Jord Corona and Tarbell Patera. Lobate plains almost completely cover up the core area of Quetzalpetlatl Corona, appear to fill a moat attached to the northern and western portions of the corona rim, and make up a distal skirt of volcanic materials outside the corona. Lobate plains clearly embay all units from pdl up to pwr_1. There is no direct contact between pl and pwr_2 but since pwr_2 is deformed by wrinkle ridges and pl is not, we conclude that pl is younger. Relationships between ps and pl are less clear and these two units may be partly contemporaneous. *Materials of Impact craters, undifferentiated (Cu).* These are various materials related to impact craters. The unit includes materials of the central peak, floor, walls, rim, continuous ejecta, and ejecta outflow materials. Materials of impact craters in the territory of V-61 mostly appear to have pristine morphology. The largest impact crater within the map area, Meitner (55.62°S, 321.6°E, 149 km), however, is apparently embayed by smooth plains.

The above stratigraphic column, which is applicable to the area of V-61 quadrangle, is generally similar to those for the Lavinia and Atalanta basins and Ganiki Planitia. However, the set of units which composes the surface of the V-61 quadrangle appears incomplete. For instance, there is no evidence there for the presence of tessera (t) and fracture belts (fb) which are widespread throughout the territory of Lavinia, and concentrated along the margins of Atalanta, basins. Although there is a significant block of tessera east of Quetzalpetlatl Corona (Quadrangle V-56), there are no tessera fragments inside the area of V-61. This could be due to complete flooding of tessera pieces by later volcanic materials within the map area. However, both densely lineated plains and tessera appear to have comparable topography and sometimes the tessera appears to have higher relief. This suggests that the separation of tessera from pdl simply by flooding appears implausible. Thus, the presence of pdl in the territory of V-61 Quadrangle and the lack of tessera there suggests that the quadrangle may represent a large area on Venus where tessera did not form.

Tentatively, we may conclude that the areas we have mapped so far, V-4, V-13, V-55, and V-61 are characterized by a broadly similar geologic history which, however, is different in detail. More detailed mapping of V-61 will further document the differences in the evolution of the basins.

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Introduction.

Planetary geologic mappers are increasingly compiling their geologic and structural maps completely within a digital domain. This not only benefits the mapper but also the publication process. As stated in the *Note to Authors Preparing Digital Planetary Maps* [1], "authors are encouraged to submit digital files whenever possible." That document lists commonly used graphical and image-processing software tools as generating some of the acceptable file formats. While these formats are great for producing published maps, we also plan to convert these digital files into a format compatible with a Geographic Information System (GIS) for visual overlays, analysis, and use on the World Wide Web. This paper will attempt to list some of the tools we have begun to use at the U.S. Geological Survey, Flagstaff, Arizona, for compiling maps in a GIS or that can be easily converted to a GIS.

GIS compilation.

The benefits of compiling a geologic map in a GIS system are too numerous to list completely. These tools give the users the ability to overlay registered base maps, topography, high-resolution imagery, and thematic physical-property maps, to name a few. For Mars mappers, Mars Orbiter Laser Altimetry (MOLA) data is turning out to be a great "false-image" mapping base. A MOLA shaded relief map can reveal features that are not apparent in available imagery. Shading can be generated to simulate any sun angle, which can help to resolve subtle and/or linear topographic features. Slope, contour, and slope-aspect (orientation) maps may also be generated. While GIS tools are great for analysis and visualizing, we have found that their learning curve is high and their editing tools unwieldy. Though some may be hesitant to invest the money and time into learning a GIS, we feel that the benefits will ultimately outweigh the costs.

As one compiles a geologic map, GIS programs allow the user to characterize each feature with an attribute. This attribute can be assigned a unique color or fill pattern, thus significantly reducing attribute errors. Most GIS programs also have specialty line and polygon editing routines like intersecting, unioning, and subtracting. Once a contact is complete, adjacent polygons can be added that share borders with a preexisting polygon. The user can also add features in any projection supported and switch to a different projection at any time.

At the USGS in Flagstaff, we mainly use the GIS program ArcView [2] by Environmental Systems Research Institute (ESRI). This program is the most popular desktop GIS system, but it is rather expensive. We heavily support ArcView with new planetary tools and tutorials, but many other good GIS tools exist. Programs such as MapInfo [3], Erdas [4], ErMapper [5], Envi [6], and ect [7] all have mapping tools. Manifold [8], probably the cheapest GIS with a graphical user interface, also has great potential (albeit this software only works on PC's).

A goal that we have at the USGS is to make web editing of GIS-based maps freely available to the planetary mapping community. Though this technology currently exists in PIGWAD [9,10], it has not fully matured. This technology will ultimately allow the user to visualize multiple datasets and to add, edit, and attribute maps in an online environment.

Adobe Illustrator and Canvas.

Illustrator [11] and Canvas [12] specifically perform digital drafting. Both these programs come with a wealth of editing tools, although some may find that these programs also require a high learning curve. These tools allow multiple layers to be visualized, but the user has to manually coregister and scale multiple datasets. These programs also must rely on other programs to generate derivative products such as shaded relief maps. Illustrator and Canvas also do not come out-of-the-box with any tools to attribute their features with additional information such as unit names, although colors can be used to delineate units. During the conversion to a GIS format, these unique colors can be converted to unit attributes.

In order to give Illustrator some GIS-like capabilities, a plug-in called Map Publisher [13] can be installed that allows the user to add features using the normal Illustrator tools but also gives the user access to attribute the map with tabular data. This program also supports many different projections, although we have not analyzed if it has the capability to define spheroids for planetary work.

Longitude and Latitude.

Unlike Earth, most other bodies in our solar system are defined with a positive-west longitude system. Although this seems like a trivial problem, most GIS and remote-sensing applications cannot handle this longitude system. While a simple shift in longitude values fixes the problems, there is a lot of potential for confusion. We use a positive-east longitude system for our digital GIS files, but for output we use the positive-west convention for referencing and labeling.

Many current and future instrument teams will be using a positive-east coordinate system and a planetocentric-latitude system for all of their martian products. The conversion from planetocentric to our current standard system, planetographic, is not just a simple latitude shift. Although the conversion equation is simple, when dealing with imagery it requires a resampling step. This has caused much concern in the planetary community since there are thousands of older maps and papers that reference the positive-west coordinate system and planetographic system. Even with this concern, there is a push to change Mars and possibly all bodies to use a positive-east, planetocentric system. While the transition may be unpleasant, in the long run it will make using commercial programs and handling digital files much less confusing.

Summary.

Digital mapping may be frustrating and a little expensive to get started, but the user will ultimately benefit. After maps are complete, the data can be further exploited for analysis. These datasets also can be readily modified and updated. If the planetocentric system is approved, it will be easy to translate any geologic or structural vector map to the new system.

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GEOLOGIC MAPPING OF AQUEOUS SEDIMENTARY BASINS ON MARS. T. J. Parker and B. J. Franklin, Jet Propulsion Laboratory, California Institute of Technology, Mail Stop 183-501, 4800 Oak Grove Dr., Pasadena, CA 91109, timothy.j.parker@jpl.nasa.gov.

Introduction: We have been interested in the aqueous sedimentary evolution of the martian landscape since the end of the Viking missions to Mars in the early 1980's. Because Mars is intermediate in size between Mercury and Earth, it has been able to retain an atmosphere and climate over geologic time. In its early history, in particular, Mars' climate was more like that of Earth, with abundant evidence for flow of water across the surface and accumulation of massive layered deposits of sediments, possibly lacustrine or marine in origin, in many places across the planet. In this abstract, we will briefly summarize the progress and results of prior mapping tasks and describe our plans for future mapping.

Argyre in the Digital Age: Geologic mapping of the MTM –45036, –45043, –50036 and –50043 quadrangles was done on the old brownline base maps in the early 1990's. This work, the geologic unit descriptions, and interpretations were included as a chapter in Parker (1994). An early review of the geologic maps by Dave Scott resulted in the suggestion that all four quadrangles be combined into a single 1:1,000,000 scale geologic map. A number of observations made subsequently resulted in the addition of a number of geologic units to those described in Parker (1994) that seem to indicate long-term geomorphic degradation of the basin's original morphology over time and the accumulation and deflation of massive deposits of fluvial and lacustrine sediments within the basin.

The recent acquisition and release of large numbers of Mars Orbiter Camera (MOC) narrow angle (NA) images and high-resolution Mars Orbiter Laser Altimeter (MOLA) topography has enabled the detailed examination of the basin's geology and topography, which has allowed us to evaluate many of our inferences regarding the evolution of the basin. (The MOLA topography is so good, in fact, that we plan to incorporate contoured topographic maps in our current and all our future map work). Happily, many of the inferences made before Mars Global Surveyor (MGS) appear to have been corroborated by MOC and MOLA data.

In the global context, MOLA has verified that Argyre is indeed the source for catastrophic floods through the Chryse trough during the Noachian. Parker (1985, 1994) was first to describe catastrophic flooding from a large lake or sea within Argyre through the Uzboi-Holden-Ladon-Margaritifer Valles system during the Noachian, though the channel connection to Argyre had been recognized during the mid-1970's, based primarily on Russian orbiter images taken at that time. Before MOLA, many investigators were unsure-which way Uzboi Vallis actually flowed, and the connection to Argyre was even less obvious.

The MOLA topography has also verified the gross topographic similarities between the rims of Argyre, Hellas, and many of the fretted terrains around the periphery of the northern plains. Parker (1997) suggested that this similarity is attributable to similar processes acting in all three locations. Once again, the quality of the data available at that time was simply not sufficient to draw a definitive conclusion.

Finally, the origin of the sinuous ridges--the "esker-unlike ridges" (so-called in protest to the recent revival of the genetic term "esker-like")--can now be examined based on MOC and MOLA data. The ridges in Argyre are not temporally associated with putative glacial landforms--the ridges are Noachian to early Hesperian in age, whereas the overlying debris aprons in Charitum Montes, typically attributed to rock glaciers and even glacial flow, are upper Amazonian. This age difference holds for the Dorsa Argentea ridges relative to the polar layered terrain as well, though the age difference is not as obvious as in Argyre. The ridges are NOT eskers. Once again, because it is important that this point not be missed: the sinuous ridges are NOT eskers. They maintain too nearly constant an elevation along their crests, with adjacent ridges having essentially the same peak elevation. They are broad, low, continuous features hundreds of kilometers long, unlike terrestrial eskers which are comparatively narrow and steep-sided, discontinuous, and rise and fall in height down-esker (though they will generally follow regional slopes). The Dorsa Argentea ridges occur in direct association with a fan or delta structure at the mouth of Surius Vallis. Deposits (and the ridges) emanating from this fan are clearly seen in the MOLA topography and appear deflected along the margin of the basin to the east of the mouth of the valley. This suggests deposition into a lake within Argyre, with littoral current deflection of sediment deposition primarily to the east of the channel. The floor of the basin west of the fan appears relatively unaltered by deflation (similar to the plains south, but not north, of Oceanidum and Octantis Montes), and yet there is a sharp drop in elevation from the west edge of the fan/delta feature in the MOLA topography, suggesting a site of relative non-deposition west from the channel. In this interpretive scenario, the sinuous ridges are coastal barriers and spits, as proposed by Parker and others (1986).

Status of East Acidalia Mapping: At about the same time Head and others (1999) described broad topographic terraces in Utopia basin, mapping co-investigator Brenda Franklin realized that similar terraces are evident in the topography in the east Acidalia/west Deuteronilus Mensae region, where we had extended our proposed shoreline maps into MTM 45347, 45352 and 45357. In this area, the proposed shorelines parallel topography and often fall along what appear to be erosional escarpments, though not preferentially either at the top or at the base of the escarpment. These escarpments appear subdued relative to the proposed shorelines, with the surface textures associated with the proposed shorelines overlying the subdued topography. The escarpments, and associated broad topographic terraces between them, appear similar to those described by Head and others (1999) in Utopia, in that they are difficult to see even in regional Viking Orbiter images unless associated with prominent contacts between geologic units. If these features are old coastal terraces that predate the "contacts" identified in Viking and MOC images (for example, Parker and others, 2001), then a detailed examination of the MOLA topography may reveal additional, similarly degraded topographic terraces parallel to the dichotomy boundary, possibly even at higher elevations than those identified to date.

Proposed Shoreline Map of the Northern Plains: Beginning in FY 2002, we hope to produce a global proposed (or interpretive) shoreline map of Mars. We have received requests from members of the community for high-resolution "shoreline" maps of the northern plains. The global maps included in the previous publications (Parker and others, 1989, 1993; Clifford and Parker, 2001) are too generalized and too small-scale to offer more than an approximation of their positions. This was sufficient to place the regional examples into global context, but it is not sufficient for testing the horizontality of the mapped contacts globally. In addition, the putative shorelines in the Utopia basin and in the plains north of Alba Patera of Head and others (1999) have shown that a number of broad topographic terraces may not be apparent in the image data, possibly due to subsequent draping by younger deposits. This possibility has prompted us to begin a new search for similar features using high-resolution topographic contour maps based on released MOLA data. Our initial search has revealed a number of previously unrecognized erosional terraces along the dichotomy boundary that will be mapped in addition to the distinct "contacts" identified thus far. We propose to include these features in a global "interpretive shoreline map" of the northern plains and crustal dichotomy, that will use the new MDIM 2 map base (or MDIM 3 when it becomes available) and contoured MOLA topography. This map will enable interested investigators to compare the proposed shoreline locations with global topography and geomorphology in their own studies.

GEOLOGY OF THE MTM 40012 QUADRANGLE, MARS

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MTM 40012 quadrangle is one of a set of eight quadrangles to be mapped in order to assess the nature of the dichotomy boundary where this boundary appears gradational and to investigate the origin of the material that is deformed into the giant polygons of Acidalia Planitia. The quadrangles to be mapped include MTM 35007, 35012, 40007, 40012, 40017, 45007, 45012, and 45017. These were selected to provide two overlapping rectangular blocks, one to address the dichotomy boundary, the other the Acidalia polygonal terrane. MTM 40012 is the first of these eight to be studied, and the first draft for this quadrangle is not quite completed. Mapping has been carried out on transparent overlays on individual Viking images. Most of the quadrangle is covered by excellent Viking images with resolutions between 42 and 46 m/pixel, and mapping directly on these images permitted assessing subtle relations among units not as readily resolved on the base mosaic. Transfer of the geology from the individual Viking images to the digital base using Adobe Illustrator is underway, but this process is very time consuming because of the level of detail that can be mapped and thus is not complete as of mid-June 2001.

Most of MTM 40012 is surfaced by a homogeneous plains unit having a generally uniform, intermediate albedo. Brighter streaks occur locally, but these appear superficial. In places, the homogeneous plains are superposed by small, high-albedo spots and patches. Many of these are resolvable at Viking resolution as circular constructs between about 0.5 and 1 km in diameter with summit pits; these are almost certainly cinder cones, an inference supported by a MOC image that includes one of them. Other, smaller spots are resolved by MOC images as irregular pits generally less than 100 m in diameter. Locally patches of high-albedo material up to several kilometers across are superposed on homogeneous plains. Plains with high-albedo spots are mapped as speckled plains, and plains with high-albedo patches are mapped as mottled plains. However, the plains material in all three units appears to be identical, the only difference being the presence or absence of younger, superposed spots and patches of high-albedo material. All of the high-albedo material is inferred to be volcanic.

Knobs and mesas ranging in size from the limit of resolution of the Viking images to at least 10 km across are very abundant. Several important issues arise with respect to these features. First, how were the knobs formed? By analogy with the southern part of Utopia Planitia it is likely that many are inliers of an older surface showing through younger plains. On the other hand, it clearly is possible that many are buttes and mesas eroded until entirely in slope. Finally, it has been proposed by others that at least some are actually volcanic constructs. These remain as outstanding issues. Additional issues arise with respect to the origin and age of buttes and mesas. Most likely, these are erosional remnants of a now eroded plateau (or more than one plateau—at least 2 mesa levels can be defined), but an important but yet not answered question is whether these plateaus were formed and eroded before emplacement of the widespread plains units, or were formed and eroded after emplacement of these plains. The latter model implies that the presently exposed plains surface, including the giant polygons, is an erosionally stripped surface.

Because both the origin of polygonal terrane and the nature of the dichotomy boundary in the Acidalia area are regional problems, results from mapping of a single quadrangle can provide only incremental information. Thus it is too early to assess what this mapping project has contributed to our understanding of these two important problems.

GEOLOGIC MAPPING OF THE CIRCUM-HELLAS HIGHLANDS OF MARS

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Introduction. Geologic mapping studies coupled with geomorphic analyses are being used to characterize ancient cratered highland terrains surrounding the Hellas basin. The spatial and temporal variability of highland evolution is being evaluated by comparison of mapping results in three regions: (1) seven MTM quadrangles covering Reull Vallis and adjacent plains and highlands, (2) two MTM quadrangles in Terra Tyrrhena that exhibit a large valley network dissecting cratered highlands, and (3) three MTM quadrangles in eastern Promethei Terra where the ridged plains contact knobby plains and rugged highlands. MTM mapping complements earlier investigations of the eastern Hellas region of Mars, including regional analyses [1–3], volcanic studies of Hadriaca and Tyrrhena Paterae [4–6], and mapping studies of highland outflow channels [7]. Current mapping studies are designed to provide new constraints on the styles and timing of volcanic, tectonic, mass-wasting, fluvial, and potential lacustrine processes that have contributed to the complex geologic record preserved in the circum-Hellas highlands.

MTM Mapping Studies of the Reull Vallis Region. Analysis of the Reull Vallis region includes preparation of three formal mapping products: (1) Geologic Map of MTM –40252 and –40257 Quadrangles [8], (2) Geologic Map of MTM –45252 and –45257 Quadrangles [9], and (3) Geologic Map of MTM –30247, –35247, and –40247 Quadrangles (compiled on a single 1:1M scale base) [10]. Crater-size frequency distributions compiled in the regional study of Mest [6, 11] have been utilized along with photogeologic observations in MTM mapping for martian time-stratigraphic designations and will also be compared to crater statistics compiled for the Terra Tyrrhena and eastern Promethei Terra regions. Maps of MTM –40252, –40257, –45252, and –45257 quadrangles in digital format are available at:
http://viking.eps.pitt.edu/public/maps/maplinks.html.

New MTM Mapping Studies: Terra Tyrrhena and Eastern Promethei Terra. Base materials and funding for geologic mapping investigations of regions within Terra Tyrrhena and eastern Promethei Terra were received in May 2001. Scientific objectives and preliminary observations for these analyses are presented herein. Within Terra Tyrrhena, MTM –20272 and –25272 quadrangles (17.5°–27.5° S., 270°–275° W.) contain an extensive (~400 km long) dendritic valley network system that dissects a cratered highland surface and loses definition near a low-lying, more lightly cratered expanse of plains. Additional smaller valley networks are found on the cratered plateau and adjacent to crater Millochau whose floor contains a partially eroded deposit with terraced hills. Key scientific issues for MTM –20272 and –25272 quadrangles include: (a) characterization and potential subdivision of the dissected plateau north of Hellas to foster detailed stratigraphic comparisons around the basin, (b) descriptive and quantitative analyses of fluvial systems, and (c) documentation of crater morphologies and effects of erosion and infilling, including identification of potential lacustrine environments.

MTM –35237, –40237, and –45237 quadrangles (32.5°–47.5° S., 235°–240° W.) include part of Promethei Terra to the east of the previously studied Reull Vallis region. This area contains the ridged plains of Hesperia Planum, cratered plateau and highland regions, and knobby plains that appear to be the remnant of an older extensive plains unit. Key scientific issues for MTM –35237, –40237, and –45237 quadrangles include: (a) the origin and modification of ridged plains, including documentation of sedimentary contributions, (b) evaluation of the ridged plains as a stratigraphic referent, (c) the resurfacing and erosional history of cratered terrains, and (d) the stratigraphic position and origin of the knobby plains, with specific comparisons to large depositional events adjacent to Reull Vallis.

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GEOLOGIC MAPPING OF THE SOUTH POLAR REGION OF MARS.

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Introduction: Regional geologic mapping of the south polar region of Mars (>60° S.) at 1:3,000,000 scale coupled with geomorphic analyses of localized features using Mars Orbiter Laser Altimeter (MOLA) topographic data and Mars Orbiter Camera (MOC) images is enhancing our understanding of the formational and modificational histories of the south polar layered deposits (SPLD) of Planum Australe and of underlying Hesperian units. In particular, we are evaluating possible eolian, tectonic, and glacial modification of the SPLD and the roles of (1) volcanism, (2) melting of polar ices, (3) impacts, and (3) volatile activity in the formation of the Dorsa Argentea Formation (DAF). Previous regional geologic maps of the south pole were compiled from mainly kilometer-resolution Mariner 9 images at 1:5,000,000 scale by [1] and from 200- to 300-m-resolution Viking images at 1:15,000,000 scale by [2].

Mapping Results: During the Noachian, the south polar region of Mars underwent intense cratering, construction of three groups of apparent volcanoes, widespread contractional deformation, resurfacing of low areas, and local dissection of valley networks. No evidence for polar deposits, ice sheets, or glaciation is recognized.

South polar Hesperian geology is characterized by waning impacts, volcanism, and tectonism. Emplacement of the polar Dorsa Argentea Formation (DAF) occurred during the Hesperian. Previously, the DAF was divided into two members by [2] on the basis of stratigraphic position and degree of degradation. We have further clarified stratigraphic, morphologic, and topographic relations, permitting the dividing of the DAF into eight members [3], which surround and underlie about one-half of the Amazonian SPLD. The DAF now includes six major plains units in (a) northern Argentea Planum (64°-81° S., 18°-104° W.), (b) Parva Planum (71°-81° S., 85°-130° W.), (c) southeastern Argentea Planum, (d) Sisyphi Planum (61°-77° S., 327°-18° W.), (e) Promethei Planum (77°-84° S., 230°-315° W.), and (f) Chasma Australe (80°-87° S., 258°-283° W.). These units are tens of meters to 200 m thick and have lobate fronts but lack typical lava-flow structures. The cavi and rugged members of DAF include irregular depressions that penetrate the subsurface; some of the pits have raised rims.

The formation and modification of the SPLD dominate south polar Amazonian geology [4]. The layers lack significant deformation throughout, and correlative sequences of flat-lying strata occur between adjacent troughs. Surfaces beneath the SPLD do not appear glaciated or fluvially dissected. The 20-km-diameter McMurdo crater in the SPLD has produced pronounced secondaries but not lobate ejecta.

Interpretations: We suggest that the DAF plains units are debris flows that may have originated by the discharge of huge volumes of slurry fluidized by ground water and/or CO_2, perhaps triggered by local impacts, igneous activity, or basal melting beneath polar deposits [3]. The cavi and rugged members may have formed by collapse due to expulsion of subsurface material in which local explosive activity built up the raised rims. Further, smaller eruptions of volatile-rich material may have resulted in narrow, sinuous channel deposits within aggrading fine-grained unconsolidated material perhaps produced by gaseous discharge of subsurface volatiles; preferential erosion of the latter material could have produced the Dorsa Argentea-type sinuous ridges associated mainly with the DAF. Alternatively, the ridges may be eskers, but the lack of associated glacial and fluvial morphologies casts doubt on this interpretation [5, 6].

The McMurdo secondaries indicate that the SPLD may be composed of porous, unconsolidated materials. Lack of intense deformation of the SPLD and erosion of underlying surfaces indicate that the SPLD have not experienced significant plastic flow or basal melting. Wind scouring most likely formed the SPLD chasmata, based on the preservation of underlying craters and sinuous ridges. Because of the lack of unconformities and discontinuities in the layered sequences, trough migration due to preferential ablation of sun-facing slopes [7] or to accublation [8] cannot be demonstrated. We therefore postulate that the SPLD were deposited and then eroded into their present form without extensive deformation or redeposition [4]. Large, cuspate ridges in the Ultimi lobe of Planum Australe appear to be layered and may be unusual erosional remnants of a once thicker sequence in this area.

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RECENT VARIABLE INFILLING OF THE UTOPIA IMPACT BASIN: REGIONAL PROVENANCE AND PROCESSES. J. A. Skinner, Jr.[1,2], K. L. Tanaka[1], [1]U.S. Geological Survey Flagstaff Field Center, 2255 North Gemini Drive, Flagstaff, AZ, 86001, jskinner@usgs.gov; [2]Department of Geology, Northern Arizona University, Flagstaff, AZ, 86011.

Introduction. Topographically, the lowlands are a collection of overlapping quasi-circular depressions [1-2], each a separate sedimentary province [3], reflecting both regional and local processes of sedimentation. Lowland materials were emplaced largely as a result of the erosion and downslope transport of adjacent highland rocks, creating a record of long-term infilling. Here we review geologic mapping results from the region defined by 0° to 60°N/210° to 270°W that delineates the more recent evolution of deposits within and peripheral to the Utopia impact basin (Figure1), as initially identified and described by [4]. This region is ideal for analysis of martian "sequence stratigraphy" for several reasons: 1) nearby topographic rises served as suppliers of sediment 2) the enclosed Utopia depression forms a distinct sedimentary province, and 3) the potential for multiple interacting geologic processes as a result of diverse geology, elevation, and latitudinal variations. Stratigraphic relationships determined from the integration of MGS and Viking datasets offer spatial and temporal constraints to the processes that contributed to lowland deposition and erosion.

Basin Characterization. Within the study area, the major topographic controls on basin sedimentation are the Elysium Mons volcanic rise, the highland/lowland boundary, and the basin itself. The basin was initially identified by [4] based upon the distribution of surface geology. MOLA-derived (DEM's) confirm the topographic signature of a ~3000 km circular depression centered at ~24°N/246°W while MGS gravity data identified a giant Utopia basin (roughly Hellas-sized) showing anomalous gravitational mass excess [5]. Viking and MOC derived crater distributions identify a general lack of craters <40 km in diameter (D<40) on the floor of Utopia basin, while a lack of smaller craters (D<6 down to tens of meters) exists along the eastern basin periphery within the boundaries of previously mapped channel deposits (*unit* Ael_3 of [6]). These characteristics indicate that 1) the depression is likely an ancient giant impact, 2) the basin has experienced Hesperian and Amazonian infilling with sediment, 3) basin sedimentation was spatially variable, resulting in differing crater distributions, 4) Elysium Mons was likely the largest and most recent supplier of volcanic and sedimentary debris, and 5) shallow basin infilling from Elysium has potentially occurred during the last 10's of millions of years.

Channelized Terranes. Variously interpreted materials [e.g., 7-10] emanate from the northwest flanks of Elysium Mons and flow over very low slopes (generally <0.05°) to partly infill the Utopia impact basin. These materials represent the latest phase of widespread deposition within Utopia and Elysium Planitiae. Sourcing from grooved, fissure, and trough terranes within Elysium and Galaxias Fossae, the channel materials likely represent episodic debris flows mobilized from the melting of ground ice by dike and sill heating and intrusion along fractures within the volcanic edifice. These resultant materials form a lobate deposit with a roughly symmetric concave-up surface profile (in the cross-deposit direction) that extends nearly 1500 km from the base of Elysium Rise into Utopia basin. Underlying ridge and scarp features, ejecta blankets, and regional basin gradients provide primary control of channel migration and distribution. The overall positive relief of the materials indicates that emplacement was largely non-erosional except where subsequent flows incised previous deposits. Subdued topographic expressions of multiple overlapping aprons and the general lack of small craters proximal to the shield indicate that the bulk of deposition resides in close proximity to the shield, where thicknesses locally exceed 500 meters. Crater distributions derived from MOC narrow-angle images correlate well with the 100 M-yr isochron established by [11].

Undifferentiated Utopia Basal Plains Material. The floor of Utopia basin is covered by undifferentiated material that embays polygonally fractured terranes of the surrounding Vastitas Borealis Formation. In the southern, lower part of the basin (<-4900 m), the unit forms a veneer of high-albedo material, while in the northern part of the basin (standing >100 m above the southern portion) the unit is characterized by dark streaks. Undifferentiated material is interpreted to be fine-grained sediment that is thickest in the southern depths of the basin.

Basin-Filling Flood Volcanism. The region south of the channel deposits consists of featureless plains previously mapped as Amazonian smooth plains deposits (*unit Aps*) by [6]; however, the occurrence of linear and lobate flow fronts traceable to the base of Elysium Mons helps identify these materials as lava flows. Similar surfaces are evident in several "windows" through overlying channelized deposits pointing both to the expansive underlying occurrence of the flood lavas as well as the braided nature of the overlying deposits. Though the sources of these materials are not readily evident, it is likely that they emanated as dike-fed extrusions from near the base Elysium Rise based upon the lack of associated vent structures and their accumulation at the marked change in slope along the base of the edifice. Abutting relations of these materials against lobate scarps peripheral to Utopia basin suggest deposit thicknesses of <500 m. Crater counts from MOC images show distributions that correspond well with the 100 Myr isochron defined by [11].

Boreal Plains. The materials that underlie the Utopia flow sequences and the basal plains, which include the Vastitas Borealis Formation, and are ambiguous due to the general covering or absence of clear contacts, making stratigraphic characterization problematic. The basin has acted as a sediment trap since its formation, likely during the Early Noachian [4-5], though evidence of earlier infilling is largely buried. The earliest record of major basin infilling resides within scattered outcrops of wrinkle-ridged plains and the extensive (16 million km^2) Vastitas Borealis Formation [6,8]. This formation consists of as-yet poorly understood Upper Hesperian material interpreted to reflect major resurfacing within the northern plains [12-13], at least in part a result of Chryse outflow activity. Polygonal grooves, broad featureless plains, and abundant lobate scarps and wrinkle ridges characterize this suite of materials, where exposures occur both north and south of the channelized deposits. Thus, these materials cover the central and peripheral regions of Utopia basin, abutting and pinching out against highland/lowland materials to the south. Crater analyses of MOC narrow angle images indicate emplacement between ~1 and 2 Ga, corresponding to the Late Hesperian [11].

Highland/Lowland Boundary Materials. An arcuate band of transitional highland/lowland materials ~400 km wide delineates the southern margin of Utopia basin, rising >3 km above the lowlands. The region grades from elevated Noachian highland materials (*unit Npld* of [6]) to closely spaced conical knobs and mesas to hummocky, collapse, and smooth materials, terminating at ~-3300 m elevation. The occurrence of rimless circular depressions, rounded hills, and subdued lobate flow fronts suggests that the lower portions of the transitional terranes have been subjected to collapse and flow processes. The stratigraphic relations between these transitional materials presently remain largely anomalous due to a lack of clear geologic contacts or embayment relations indicative of deposit evolution. However, the highland/lowland boundary materials appear progressively younger northward, contrasting with previous interpretations of youthful knobby materials bound by ancient, southern highland terranes (e.g., *units Npld* and *Hr*) to the south and *unit Hvg* of the Vastitas Borealis Formation to the north [6]. This age progression is based upon the continuity and variety of lobate scarps and ridges along the highland/lowland boundary, crater distributions of boundary materials, topographic signatures of geologic contacts, and inferred embayment of materials from the north. The progressive degradation of the dichotomy boundary appears to have fed sediment toward the Utopia basin through a variety of processes.

Discussion. The record of erosion and infilling within and marginal to Utopia basin reflects complex temporal and spatial interactions of geologic processes. In unraveling the depositional history of Utopia basin and the northern plains, we would like to determine, if possible, which features have catastrophic vs. gradual origins. Similarly, a careful examination of structures within the northern plains is required to supplement and help elucidate the stratigraphic evolution of these materials. To date, we can make several assertions (Figure 2). Dust accumulation within Utopia basin, depositing undifferentiated material, likely reflects the most recent resurfacing. Interfingering and underlying the undifferentiated material are the mass-flow deposits that issued from Elysium Fossae. Punctuated deposition of these deposits likely began in the Middle Amazonian and persisted well into the Late Amazonian. However, it appears that small-scale collapse and flow debris aprons likely interfinger lava flows along the base of Elysium Rise based upon the near-equivalent age of the basin filling lava flows that underlie and fill the southern portion of Utopia basin. Deposition of these debris and lava flows appears to have been largely controlled by linear and lobate ridges of the underlying terrain, which constricted deposition to the south. The basal plains, debris flow, and lava flow materials all cover undifferentiated boreal plains materials, which encroach from the north and potentially thin against transitional materials of the highland/lowland boundary. The evolution of materials related to the dichotomy boundary presently remains obscure, though consistent contact elevations, most notably along a slope break at −3300 m, indicate no regional tectonic tilting of these materials since emplacement. However, various structural features have deformed the basin units. In particular, well-defined scarps radial and concentric to Utopia basin and wrinkle-ridge assemblages within highland/lowland boundary materials collectively indicate regional to global compressional events during the Hesperian and perhaps Amazonian.

Future Work. Determining stratigraphic boundaries in conjunction with geomorphic relations can elucidate the geologic history of the northern plains. These efforts have been greatly enhanced by MGS datasets, especially MOLA-derived topography renditions, which help identify subtle relationships that were previously unrecognizable. We aim to continue examining the depositional history of these materials, focusing on 1) local and regional similarities in the evolution of the highland/lowland boundary and its contribution to lowland infilling, 2) the timing and nature of northern plains tectonism, and 3) the role of catastrophic vs. long-lived erosional and depositional processes.

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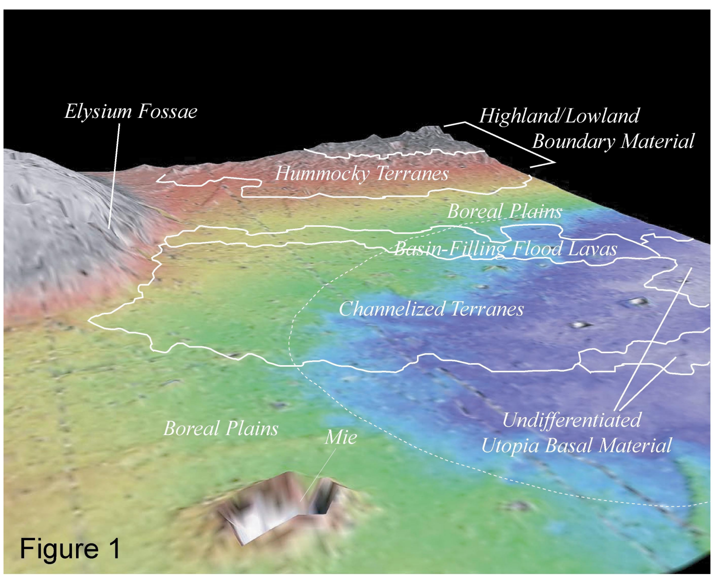

Figure 1. An oblique southwest view of MOLA DEM, showing the general distribution of terranes within and marginal to Utopia basin (dotted line). Note the distribution of linear scarps and ridges throughout the region. VE~50X.

Figure 2. Simplified stratigraphic column delineating the initial occurrence and modification of generalized terranes. The overlapping nature of depositional and modificational processes has likley resulted in the interfingering of depostional sequences within the basin.

STRATIGRAPHY OF TERRA MERIDIANI, MARS. B. M. Hynek, R. E. Arvidson, and R. J. Phillips, Department of Earth and Planetary Sciences, Washington University (One Brookings Drive, St. Louis, MO 63130) hynek@levee.wustl.edu.

Introduction: The primary hematite deposit in Terra Meridiani lies in a unique region of Mars that underwent regional-scale tilting toward the Tharsis trough due to tectonic activity associated with the formation of the Tharsis rise [1]. This tilting and perhaps accompanying climate change led to large-scale denudation of the martian highlands in and around Terra Meridiani [2]. This was followed by widespread deposition of fine-grained, post-Noachian layered materials onto the degraded cratered uplands. Stripping of the deposits has exposed a number of layered systems, including the hematite unit. Stratigraphic analyses reveal that the hematite deposit is comprised of dark plains and is situated in the middle of a complex sequence of bedforms of varying competencies.

Local Stratigraphy of Terra Meridiani: We have completed stratigraphic analysis of the Terra Meridiani region using Mars Orbiter Camera (MOC) and Viking imagery, fine-scale topographic grids from Mars Orbiter Laser Altimeter (MOLA), and high-resolution thermal inertia, albedo, and MOLA pulse width data (Fig. 1). It is becoming increasingly clear that the hematite locale is not an isolated deposit; rather, it is one bedform in the midst of a thick (~600 m) layered sequence of deposits that buries Noachian cratered terrain. Portions of the sequence are seen for hundreds of kilometers, and bedding remains remarkably horizontal and uniform.

The geomorphic units have been divided into three main categories: plains, etched, and cratered materials (Fig. 1). The plains units represent competent layers within the stratigraphic sequence that mantle underlying topography as well as abutting high-standing inliers of older cratered terrain. The upper member (P_3) consists of the youngest mapped units in the region. Dark, smooth, hematite-rich plains characterize the middle unit (P_2). The northeastern edge of the middle plains unit borders a topographic trough that exposes finely layered materials extending ~400 m below the adjacent hematite deposit. The lower unit (P_1) is a thick (~200 m) resistant member that contains some layering. Numerous outliers suggest that these units were once much more extensive.

All plains units exhibit some degree of eolian erosion, particularly on their fringes. Etched terrain (E) lies adjacent to all three plains members. It is generally very rough (at MOLA pulse and MOC scales), of high albedo, and consists of friable layers stratigraphically below, and sandwiched between, the plains units. The abundance of cliffs, mesas, pits, and troughs indicate that these materials have undergone extensive modification by wind. Some of these layers contain evidence of local reworking of material, including possible cemented dunefields.

Degraded Noachian cratered uplands lie beneath and adjacent to the plains/etched stratigraphic sequence and have been subdivided into three categories: 1) cratered, subdued uplands (Ns) with heavily modified craters lacking appreciable rims and ejecta (which were likely removed in the Noachian denudation event), 2) cratered, dissected (Nd) (upland material with a relatively dense system of valley networks), and 3) undivided cratered materials (Nu).

Formation Mechanism: A number of formation mechanisms have been proposed for the martian hematite deposit including precipitation from a standing body of Fe-rich water [3] and an igneous intrusion or altered ignimbrite deposit [4]. MOLA analyses reveal that the Terra Meridiani deposits are on tilted topography (related to the formation of the Tharsis complex), making a lacustrine origin unlikely. Further, our mapping did not reveal any lake shorelines or topographic basins. Lack of local or regional volcanic constructs or associated features and the observation that thinly bedded deposits extend unchanged for hundreds of kilometers over pre-existing topography weakens the igneous hypothesis. Whatever hypothesis invoked, it must be able to explain a ~600 m-thick, finely layered sequence of competent plains and interbedded friable units, all of which drape over pre-existing Noachian cratered uplands.

Our work indicates that the fine-grained layered sequence was most likely emplaced as airfall, either as volcanic ash or eolian-derived sediments, possibly linked to Milankovitch cycles. The unique hematite signature observed in the middle plains unit could be a result of subsequent hydrothermal alteration of the deposits or an in situ hematite-rich layer of ash. If the deposits are volcanic airfall, the most likely source would be the Tharsis volcanoes. Other stacks of alternating competent plains and friable units observed globally in near equatorial regions (including the layered deposits within Valles Marineris and Aram Chaos as well as the Medusae Fossae Formation) may be of similar origin. Lack of a continuous equatorial band does not rule out global-scale deposition from ashfall or eolian processes. The extreme degree of subsequent eolian modification observed on all these deposits has likely removed large areal portions of the units and redistributed them in global sinks, leaving the eroded stacks of deposits and the numerous outliers that we see today.

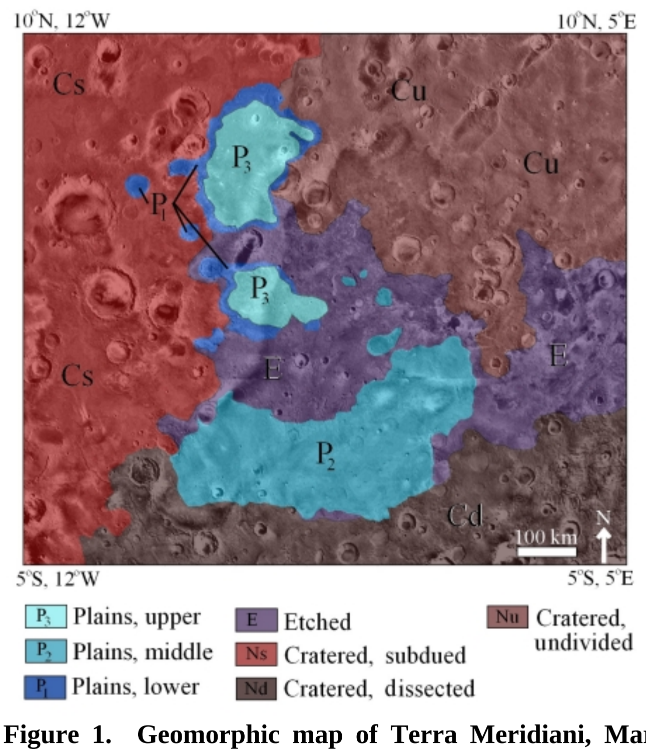

Figure 1. Geomorphic map of Terra Meridiani, Mars draped over a Viking mosaic.

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Field trip to Mars (Martian meteorites in the Institute of Meteoritics, University of New Mexico)

Approximately 20 participants of the Planetary Mappers Meeting attended a field trip to the Institute of Meteoritics in the Department of Earth and Planetary Science at the University of New Mexico. During the 2 hour visit the participants were given a short introduction to martian meteorites by Dr. Horton Newsom, including material prepared by Dr. Rhian Jones. The group then split up and were given tours of the following facilities:

The tour of the microbeam facility included observing a thin section of ALH 84001 in the scanning electron microscope. The zoned carbonates and shock melted features were a highlight of this part of the tour, led by Dr. Lars Borg and Mike Spilde.

A gloves-on tour of hand samples and thin sections of martian meteorites in the department microscopy laboratory was led by Dr. Chip Shearer. This included detailed observations of the characteristics of the martian samples relevant to remote sensing, including variations in mineralogy, texture, grain size, and shock effects.

A tour of the Meteorite Museum by Dr. Newsom and Prof. Wolf Elston included viewing the new impact crater exhibit developed by Dr. Newsom, seeing the many meteorites on display, and hearing stories from Prof. Elston about the more-than-50-year history of the Institute of Meteoritics.

A visit was also made to the stable isotope laboratory of Prof. Zach Sharp, where miniaturized laser sampling of geologic materials invented by Prof. Sharp was demonstrated. The capabilities of this laboratory include analysis of meteorites and astrobiology samples, and three isotope oxygen measurements critical for identifying martian material.

Field Trip to the Spring Deposits of the Western Rift and to the Very Large Array, New Mexico

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Travertine Quarry and Related Rift Geology

1. Drive south on I-25 from Albuquerque; here is a short description of what one sees between Albuquerque and Socorro.

- Before Isleta: The Airport Mesa is an isolated pediment surface left behind when the proto-Tijeras Arroyo thousands of years ago jumped from north of the airport to its present location south of the airport. The old arroyo is the Lomas-Menaul region.
- The Tijeras Arroyo is the principal drainage for the east side of the Sandias.
- I-25 turns west, crosses Rio Grande: the basalt cliffs up ahead are from Isleta volcano, one of the several small shield volcanoes that cluster around Albuquerque. Isleta Pueblo is built on an "island" tongue of lava from Isleta volcano. The well-bedded "sediments" beneath the basalt on south Coors here are maar deposits that were deposited during explosive initial eruptions of Isleta volcano.

2. Once past Isleta volcano and headed south on the long straight section past the outcrops of Isleta volcano basalt, one can see the Cat Hills volcanoes on the horizon to the west. The cinder cones and lava flows here are slightly younger than the Albuquerque volcanoes. The big swell at 3:30 is Wind Mesa, a faulted shield volcano. The big volcano at 1:00 is Las Lunas volcano. Tome volcano is in the valley floor at 10:00.

3. Los Lunas Volcano is a polygenetic volcanic center near the intersection of NM 6 and I-25. The volcano consists of two main periods of eruption (3.8 Ma and 1.2 Ma). The older center is primarily dacite, whereas the younger center is trachyandesite. Flows from the younger cone actually flowed down the volcano flanks and "ponded" at the base to form what appears from a distance to be mesa-like escarpment. In air photos these are easily seen as circular ponds fed by distinctly channeled flank flows.

New Mexico Travertine

Exit 191 to Belen: exit to the west. Drive up, the escarpment. Headquarters and mill for the travertine operation is on the right after about 1 mile. Note that the mill is lower in elevation than the road as you approach from the east. Just before arriving at the mill the road descends abruptly. The descent is along one of the many north-south trending fault scarps that displace the Llano de Albuquerque surface.

Here we will pick up our guide and drive west to the actual site of the travertine quarries. We will visit three distinct types of travertine. Location 1 will be the quarry for a type of travertine known as Scheherazade; location 2 is a quarry characterized by extensive brecciation and local faulting; and location 3 is an area of active travertine deposition, in this case along a drainage.

These deposits are all emerging along faults that are acting as the western boundary faults for the Rio Grande rift. Madera Limestone is the principal rock to the west of the fault; Santa Fe Group Tertiary sediments fill the rift east of the fault zone.

New Mexico has several distinct travertine depositional regions and is one of only three places in the U.S. where commercial travertine is quarried. Travertine is widespread in New Mexico. About 50 discrete deposits are known.

Travertine, composed primarily of calcium carbonate as calcite, and less commonly as aragonite, is deposited in a spring system that emits either warm or cold carbonate-charged water and deposits at or near the surface. Travertine is typically related to faults and to nearby limestone source rocks.

Belen Travertine Quarry–Mesa Aparejo (Grey Mesa)

Limestone of the Pennsylvanian Madera Formation in the subsurface to the west is probably the primary source rock for the carbonate-rich water that deposited this material. A large NE-trending fault, mapped as a normal fault dipping eastward, lies to the west of the travertine. This is probably part of the bounding fault zone of the rift in this area. With respect to the west, the Madera east of Mesa Aparejo has dropped several thousand feet into the Albuquerque-Belen basin portion of the rift. Sandstone, conglomerate, and mudstone of the Tertiary Santa Fe Group now overlie downfaulted older units and lap onto Mesa Aparejo. The fault zone acted as a conduit and continues to influence circulation of carbonate-charged ground water and spring water.

Precipitation of calcium carbonate in a spring system occurs when carbonate-rich waters become supersaturated due to either evaporation of water or loss of carbon dioxide by degassing from pressure release, turbulence, or organic activity. The latter includes photosynthesis by algae or mosses or bacterial metabolism.

Travertine was deposited as extensive thick laminar lenses at Mesa Aparejo and is presently being deposited from springs near the northern end of Mesa Aparejo. The various varieties of travertine quarried at Mesa Aparejo are distinguished by color and structure. Impurities impart the color banding. Pink and red are probably primary and derived from iron oxide from red Permian rocks. Yellow and brown are probably secondary and produced by percolating oxidizing waters. Look for serrated-edge laminations, micro-terraces, concretionary masses, rod-like structures or shrub-like forms that are believed to be caused by various organic interactions. Holes within the travertine may be from rapid accumulation over an uneven surface.

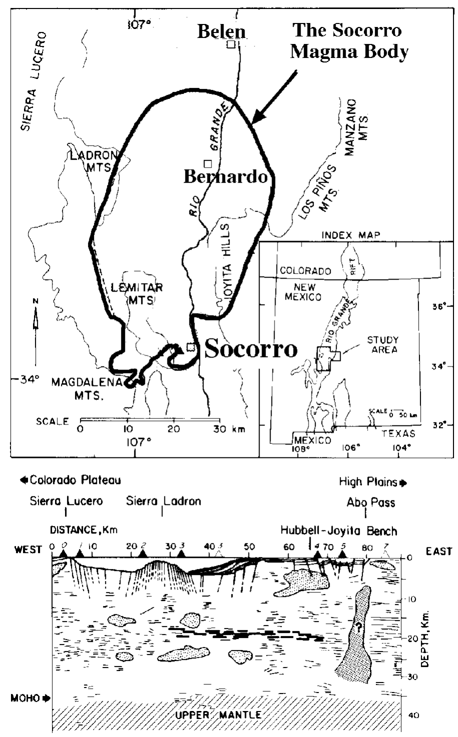
Six varieties of travertine are quarried. These varieties are laterally consistent for hundreds of feet. This wide variety of types within one deposit is very unusual. Conservative estimates are about 49 million cubic feet of commercial-quality travertine. Travertine in this region underlies about 12,140 acres and may total about 200 million short tons. The travertine is quarried and sold as slabs, rubble, or crushed stone. Names given to the various color varieties include: Temple crème, Scheherazade, Vista Grande, Desert Gold, Desert Crème, and Apache Golden Vein.

4. At Exit 195: at 11:00 is Black Butte, another mid-rift small volcano. There are probably many such volcanoes within the rift, most of which are long since buried.

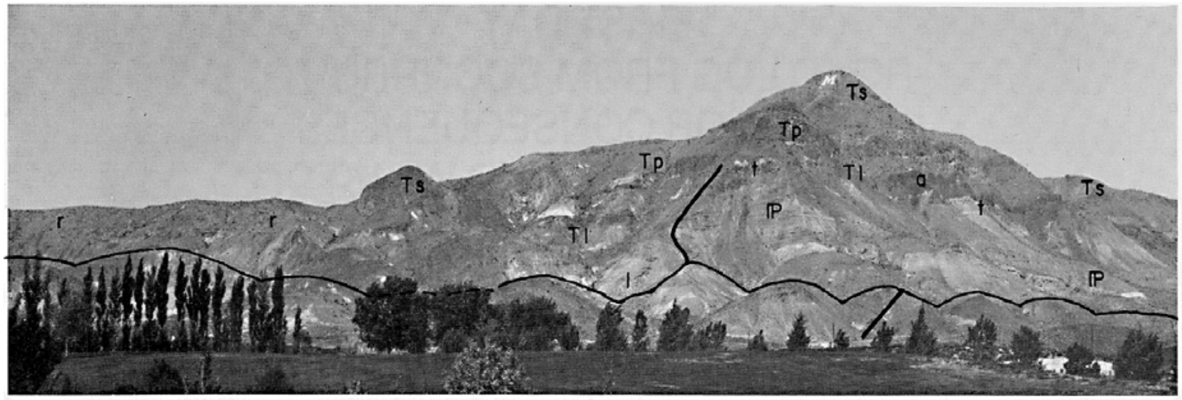
5. Bernardo exit: from here south to Socorro one travels over the Socorro magma body. The Socorro magma body is responsible for about half of all earthquakes in New Mexico. Most of the earthquakes are the result of upward propagating cracks directly over the magma body as it inflates and stretches the overlying crust. The main body lies at a depth of about 20 km, the middle of the crust, which is the typical temporary residence for many magmas until they can build up the necessary volatiles to erupt. Smaller magma bodies are believed to exist above this body at a depth of a few kilometers. This is typical of the depth from which most dikes propagate upward.

6. Servilleta exit: the river is "swampy" here because the gradient is less. One possibility is that this is a direct result of long-term uplift associated with the underlying Socorro magma body. The rate of uplift is geologically quick, so the river has not had time to cut down or readjust to the shallower gradient.

7. Rest area north of Socorro: the lumpy terrain here represents wind-blown sand and dunes that are largely stabilized by vegetation. The rest stop was originally built on the platforms to place the area above drifting sands as an overlook for extensive dunes which have since disappeared under vegetation.



Mapped extent and cross section of the Socorro magma body.



View to west of Socorro Peak from the New Mexico Tech golf course. Socorro Peak is a west-tilted late Miocene intra-rift horst which has exposed the northern topographic wall (heavy line) of the Socorro cauldron. The cauldron wall truncates Pennsylvanian limestones and shales (IP) and is buried by late Oligocene moat-fill volcanic rocks (Tl) of the unit of Luis Lopez. A large rhyolite dome (r) north of Blue Canyon probably marks the main ring fracture of the cauldron. Other moat deposits include ancient landslide deposits (l), lithic-rich ash-flow tuffs (t), and andesite-flows (a). Moat deposits are unconformably overlain by lower Popotosa fanglomerates (Tp). Rhyodacite to rhyolite intrusive necks and flows (Ts), the late Miocene rhyolite of Socorro Peak, cut and overlie the Popotosa Formation. The cauldron wall is offset and strata are repeated in the low hills along the base of the escarpment by a major north-trending rift fault zone (light line). (Photo by H. L. James) from Chapin et al., 1978

A group of the boys whooping it up at a local Socorro saloon in the 1880's. The cleverly contrived name of the establishment enabled the gang to remain off the domestic hook by having to work late at "our office." Could that be a bottle of Lancers in the barkeep's left hand? Photo by Joseph E. Smith, courtesy Ed Smith; New Mexico Bureau of Mines and Mineral Resources collection.

Early Socorro saloon: Note that the saloon's name is "Our Office." Think of the possibilities. Were our frontier fathers imaginative or what?

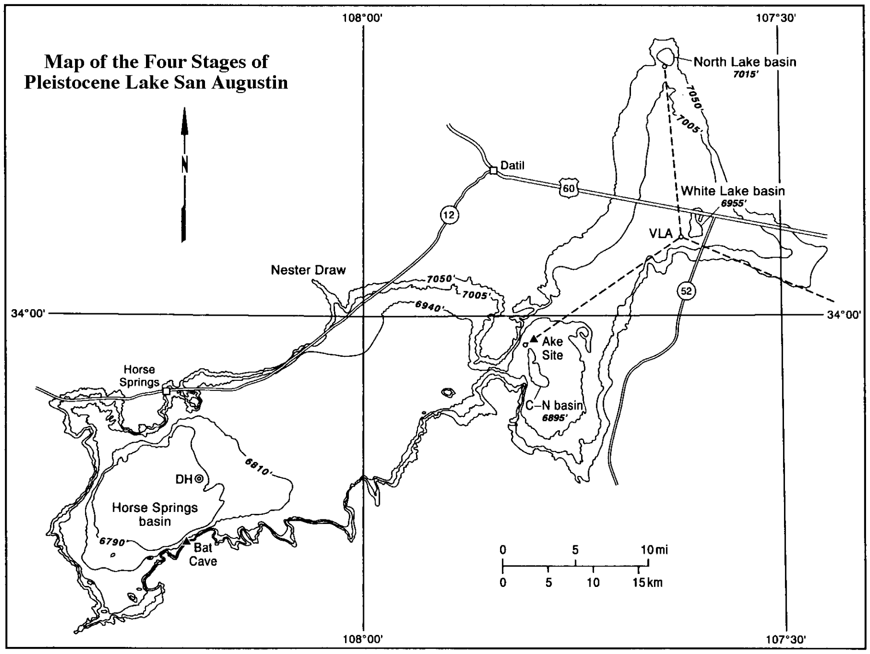
8. Socorro: The peak due west of Socorro (Socorro Peak) exposes in its east face the northern topographic wall of an Oligocene cauldron typical of the large (mid-Tertiary, Miocene) cauldrons that we will be driving around and through (see figure reproduced here) as we circumvent the Mogollon-Datil volcanic province (*aka*, Mogollon-Datil volcanic province or cauldron field). In the slopes of Socorro Peak, well-stratified Paleozoic limestones on the left are truncated by the inner caldera wall that cuts down from upper right to lower left. This is overlapped in turn by caldera-filling ash flows and rhyolite flows (late Miocene) of the peak itself.

As we drive west from Socorro, the mountain range to our west is, first, the Magdalenas and, then, set back farther to the west, the San Mateos, home of the Mt. Withington, Sawmill Canyon, and Nogal cauldrons. Whenever you see a prominent range of mountains to the west in this part of New Mexico, you are most likely looking at a mid-Tertiary ash-flow cauldron interior, specifically the resurgent dome part. It is similar to Redondo Peak in the Jemez, just older and caught up in Basin and Range style faulting. Essentially the interiors of most cauldrons are "hard cores" of thick ash flows and deeply rooted granitic plutons. So they resist faulting and erosion and are preserved as mountain ranges.

9. Town of Magdalena Silver was discovered near Magdalena in the 1880's, but the real boom was lead-silver. Nine million dollars of lead-silver was mined between 1880 and 1902. The Kelly Mine, near Magdalena, is also a source of smithsonite (the New Mexico state mineral). Today Magdalena is an artist's community.

The Plains of San Agustin: The Very Large Array

The Very Large Array is arranged across the floor of the late Pleistocene San Agustin lake basin. This flat-floored valley, once the site of a 50 mile long lake is a graben downdropped between parallel faults, with three sub-basins that are interconnected by channel ways. The three sub-basins are While Lake (2119 m floor elevation), C-N Lake (2101 m) and San Agustin Lake (2065 m). Beach ridges are found from 2134 to 2082 m elevations and suggest a lake that at one time connected all three basins. Later lowering of the lake level led to separation of the basins and ultimate desiccation of the lake. At the maximum lake level, the lake had a total area of 1200 km^2 and was about 70 m deep in the deepest part.



Two cores taken in the deepest part of the basin show a continuous record of sediment texture and pollen down to about 300 m. A radiocarbon date of 27,000 yrs from the upper 10 m and Tertiary pollen below 280 m suggest a long record from the Pliocene. Sedimentation rate appears to have been variable, and post-deposition removal of sediment occurred in mid-late Holocene by erosion.

Horse Mountain dominates the western side of the San Agustin graben and is the core of an eroded stratovolcano. Small isolated butte north of highway consists of Horse Mountain lava flows that are the same as those in Horse Mountain (northeast ridge). This block may be dropped down via a fault along the range front. The age of the Horse Mountain eruptions is around 14 Ma.

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2001 PLANETARY MAPPERS MEETING

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