ADVANCES IN RECONSTRUCTING THE GEOLOGIC HISTORY OF THE CHRYSE REGION OUTFLOW CHANNELS ON MARS. K. L. Tanaka[1] and J. A. Skinner, Jr.[2], [1] U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001, [2]Environmental Geomatics, 719 New Road, Raleigh, NC 27608, jimbo_skinner@yahoo.com.

Introduction: We have updated our geologic mapping of the northern plains of Mars, based on analysis of Mars Odyssey (MO) Thermal Emission Imaging System (THEMIS) images and Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA) and Mars Orbiter Camera (MOC) data. One of our objectives in the mapping has been the reconstruction of Chryse region outflow channel activity. Here, we present new findings that bear on channeling history, the northern plains ocean hypothesis, and hematite formation in Aram Chaos.

Background: The Chryse outflow channels consist primarily of, from west to east, Kasei, Maja, Simud, Tiu, Ares, and Mawrth Valles that debouch into Chryse and southern Acidalia Planitia (Fig. 1). These channel systems originate from chaos terrains and fissures, demonstrating their origin from ground fluid. Most consider that fluid to be water [e.g., 1], but carbon dioxide as an important constituent has also been considered [e.g., 2].

Many previous studies of outflow channel history, based on Viking and earlier releases of MOC and MGS topographic and morphologic data [e.g., 3-4] have established that most of the major outflow channel activity occurred during the Late Hesperian. Because of the hypothesis that the Vastitas Borealis Formation (VBF) deposit filing the northern plains may have resulted from deposition in an ancient ocean [5], some have proposed that all or most outflow channel activity was sufficiently contemporaneous to form the ocean [6]. However, we have pointed out that the geologic story regarding outflow channel history and ocean formation is far from clear. For example, scouring associated with the outflow channels does not define a base level [4]. Also, the VBF embays the outflow channels (Fig. 1); thus all or much of the outflow activity might substantially predate formation of the VBF.

Revised Chryse region stratigraphy: Our present mapping only includes the region north of the equator and excludes the upper, southwestern part of Kasei Valles (Fig. 1). Based primarily on crosscutting relations as well as other clues, we have mapped six Chryse channel-related units at 1:15,000,000 scale. *Chryse units 1-4* (units Hc_{1-4}) and the *Ares unit* (unit Ha) form deposits within the outflow channels and Chryse Planitia. We do not map the scoured upper reaches of channel floors as channel units (as in previous mapping [e.g., 3]), but infer the exposed bedrock units, which consist of Hesperian and Noachian materials. The *Simud unit* (unit Hs) forms the undifferentiated chaos materials located at the heads of Simud, Tiu, and Ares Valles. Relative ages of the Chryse, Ares, and Simud units are based on superposition relations as well as preliminary crater counts (no. > 5 km in diameter per 10^6 km^2, or N(5)).

Chryse unit 1, N(5) = 236±23. This unit forms Late Noachian deposits in Chryse Planitia, exposed mainly on the plains margins. Most outcrops form plateaus tens to hundreds of meters high. The plateaus appear to be erosional remnants of former, more extensive deposits. In addition, we consider the floor of Maja Valles within Chryse Planitia to be made of this unit because of the shallow depth of scouring probably has exposed little of the underlying Noachian material. The paucity of ghost craters in Chryse Planitia [4] indicates that resurfacing associated with this unit (which might include erosional planation) was sufficient to obscure earlier Noachian landforms across most of the Chryse plains. However, a few large craters in eastern Chryse Planitia may have escaped channel-related obliteration and be Early to Middle Noachian. Source channels for this unit might include both early dissection of the large outflow channels as well as dissection from numerous sinuous channels occurring sporadically throughout the Noachian rocks surrounding Chryse basin. An increasing number of these channels are being recognized in THEMIS data.

Chryse unit 2, N(5) = 108±22. This unit embays Chryse unit 1 and makes up higher-standing plains outcrops on the margins of Chryse Planitia and is inferred to form some channel bars in northern Chryse. In northwestern Chryse, the unit appears to be sourced from fractures and troughs near lower Kasei Valles. In southwestern Chryse, the unit appears to be associated with Maja Valles, including secondary channels that spilled over the highland margin at various points. Northeastern outcrops may result from major outflow channels and local, smaller channels.

Ares unit, N(5) = 35±17. This unit appears to overlap Chryse unit 2 along lower Ares Vallis. It forms low, smooth plateaus with irregular outlines and contains circular and irregular depressions in places. It mostly occurs within lower Ares Vallis and southern Chryse Planitia, including near the Mars Pathfinder site, as mapped previously [7]. In addition, we find outcrops in upper Ares Valles and within Aram Chaos. The unit appears to include a somewhat resistant cap, locally resulting in its preservation as an evenly thick plateau, in spite of later channel erosion. In Aram Chaos, the unit overlies hematite-bearing strata [8]. The floor of Aram Chaos includes some unusual hummocky and fractured surfaces. The Aram unit may have some sort of volcaniclastic or hydrothermal origin that accounts for its unusual morphology and apparently higher erosional resistance relative to that of the Chryse units.

Chryse unit 3, N(5) = 72±11. This unit makes the up youngest materials occurring locally within Kasei and Ares Valles, the wrinkle-ridged, broad plains below the mouths of Maja and Kasei Valles, and higher standing plains cut by lower Ares Vallis. Potentially, these materials might all arise from dissection of Kasei and Ares Valles only, although early Simud and Tiu Valles dissection also might also have contributed. Wrinkle ridges appear to be densest in western Chryse Planitia; the other surfaces of the unit may reflect either greater resurfacing and/or lesser contractional deformation.

Chryse unit 4, N(5) = 86±15 and Simud unit, N(5) = 79±15. These units appear to account for the youngest channel activity in the region. Simud and Tiu Valles down cut the mouth of upper Ares Valles. In addition, we have discovered primarily with MOLA data a low scarp between this unit and Chryse unit 3 in western Chryse Planitia. The unit surface includes fractures and possible mud volcanoes that have been interpreted to be resulting from deposition of debris- flow material [7]. We also now see that the surface is relatively hummocky, knobby, and wrinkle ridged compared with earlier Chryse units. Along the southern margin, scarps and depressions of the Simud unit cut Chryse unit 4. The Simud unit is made up of knobby, hummocky, and fractured materials resulting from degradation of older Noachian rocks and Hesperian Chryse units. Tongues of the VBF inundate the dissected troughs associated with unit 4 dissection and embay the northern margin of that unit.

Significantly, Chryse unit 4 and the Simud unit are much less densely marked by wrinkle ridges than surrounding plains areas, much like the VBF (Fig. 1). Also, much of the Noachian surfaces surrounding the Simud unit appear scoured and lightly ridged. We interpret the difference in deformation to mean that a long-lived hiatus in outflow channel activity occurred between Chryse units 3 and 4.

Implications. MGS and MO data sets provide for observation of clearer geologic mapping relations than previously possible. Our reconstructions indicate that the latest stages of dissection for each major outflow channel system were not all synchronous. The youngest dissection from Simud and Tiu Valles, however, could have been the greatest event in terms of volumes of rock and liquid transported from the canyon and chaos systems, given the volumes of the features potentially involved. Detailed mapping and dating of individual segments will be needed to establish to what extent the source areas were active at the latest stage of activity; it is possible that only a fraction of canyon and chaos formation was associated with Chryse unit 4. While a sedimentary origin for the VBF remains attractive, geologic relations do not soundly correlate latest outflow-channel activity with VBF origin, and thus an alternative history remains plausible [e.g., 4].

Coincidence of hematite-bearing material, rare on Mars, with the unusual Ares unit may be a significant clue to the apparently special conditions needed for forming detectable concentrations of hematite with the TES instrument. More detailed mapping of materials in Aram Chaos and hopefully results from the Mars Exploration Rover to Meridiani Planum may assist in understanding how this mineral formed at or near the surface of Mars.

References: [1] Baker V.R. and Milton D.J. (1974) *Icarus, 23,* 27-41. [2] Hoffman N. (2000) *Icarus, 146,* 326-342. [3] Rotto S. and Tanaka K.L. (1995) *USGS Map I-2441*. [4] Tanaka K.L. et al. (2003) *JGR, 108,* doi:10.1029/2002JE001908. [5] Parker T.J. et al. (1989) *Icarus, 82,* 111-145. [6] Baker V.R. et al. (1991) *Nature, 352,* 589-594. [7] Tanaka K.L. (1999) *JGR, 104,* 8637-8652. [8] Christensen P.R. et al. (2001) *JGR, 106,* 23,873-23,885.

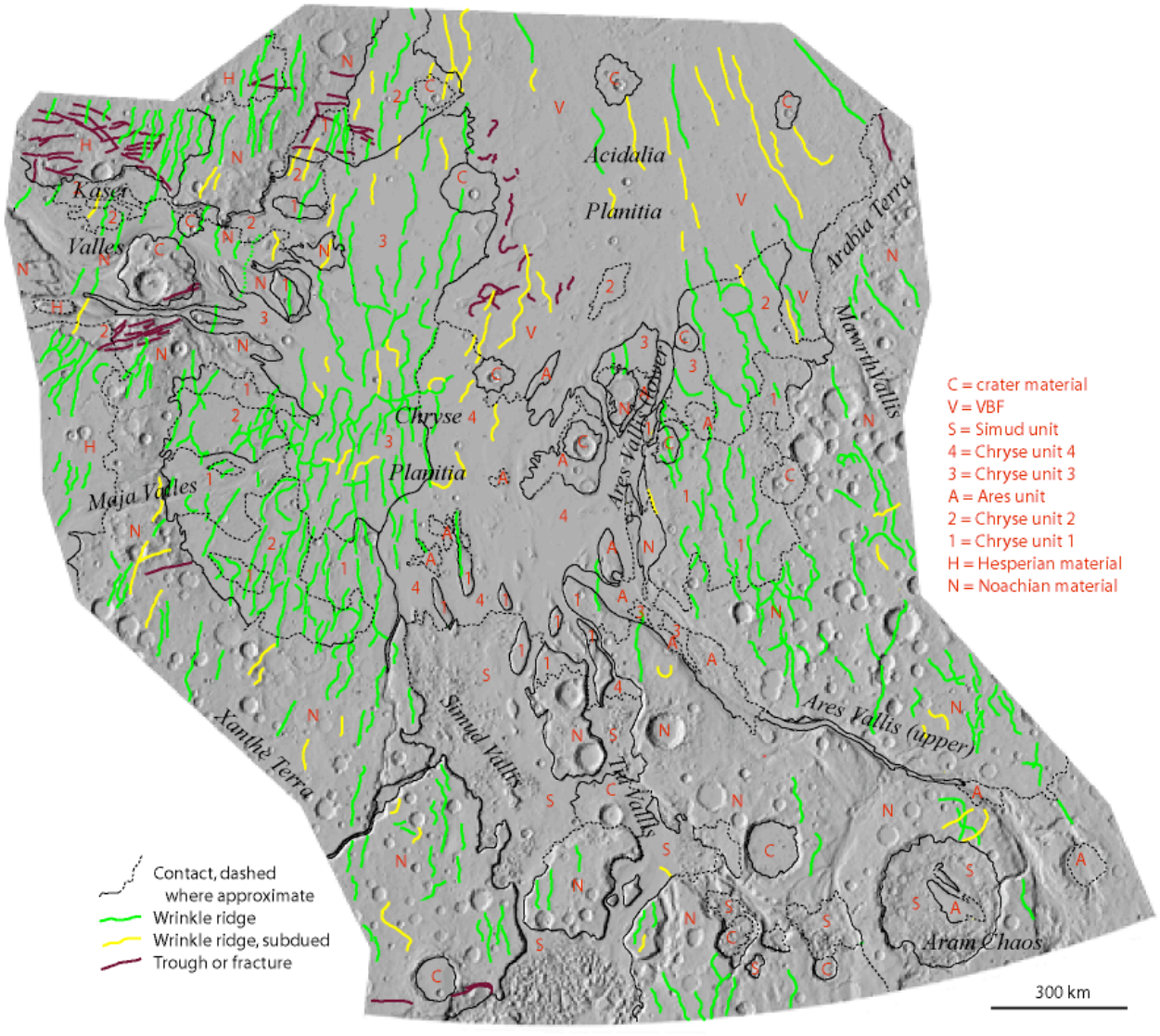

Figure 1. Preliminary, generalized geologic map of the Chryse region of Mars, showing Chryse outflow-channel related geologic units (see text). Other Hesperian, Noachian, and VBF materials are not differentiated. Note that the Vastitas Borealis Formation (VBF) embays Chryse unit 4; in turn, these and the Simud unit are much less densely wrinkled ridged than the older, Chryse units 1-3. Base map is derived from a MOLA shaded-relief digital elevation model in polar projection; the equator forms the curved lower edge and top of map is near 45°N.