"SEQUENCE STRATIGRAPHY" OF POLAR DEPOSITS ON MARS: LESSONS LEARNED.

K. L. Tanaka[1], C. M. Fortezzo[1], J. A. Skinner, Jr.[1], and E. J. Kolb[2], [1]U. S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, Arizona 86001 (ktanaka@usgs.gov), [2]Google, Inc., 1600 Amphitheatre Parkway, Mountain View, CA 94043.

Introduction: The polar regions of Mars exhibit relatively pristine sequences of mostly layered water ice and dust that form broad plateaus (Planum Boreum and Planum Australe). Recent and ongoing studies have utilized high-resolution imaging, multispectral, and radar sounding data obtained from orbiting spacecraft to determine the stratigraphic character of polar layered deposits (PLD) and how they may relate to orbitally driven climate variability [e.g., 1-12]. Here we focus on results achieved by adapting the sequence stratigraphy approach used to study sediments on Earth to mapping of the PLD. Results illustrate that this technique is vital for constraining and correlating geologic histories among various martian sedimentary sequences, which also occur in the cratered highlands, in canyons, and along the highland-lowland boundary.

Methodology: Sequence stratigraphy involves a mapping approach that provides a chronologic framework to rock strata, whereas the more common approach to mapping discriminates rock formations based on their material characteristics. The key structure that is mapped in sequence stratigraphy is the unconformity [13]. Unconformities may bound sequences of sediments that grade vertically and laterally in characterisitics such as mineralogy, bedding, and grain size, shape, and sorting [14]. Terrestrial sequence stratigraphy is applied to strata that record marine transgressions and regressions at multiple time scales due to climate-driven sea-level changes, basin subsidence, and changes in sediment supply [14]. The goals of mapping and analyzing sequences of layered deposits on Mars, at the poles and elsewhere, are commonly similar.

North PLD stratigraphy: We have delineated 5 Planum Boreum (PB) units, which from oldest to youngest are the rupes, cavi, and 1-3 units [12]. The PB rupes unit forms an ice-rich basal unit locally exceeding 1000 m in thickness and whose layers are tens to hundreds of meters thick; radar sounding data reveal its buried extent and topography, which is highly modified by erosion [6, 11]. Its crater density indicates that it was formed during the Hesperian (>3.5 Ga). Afterwards, the PB cavi and 1 units were emplaced forming sequences of ~meter-thick layers approaching 1500 m in total thickness, but their age is not well constrained (perhaps Middle to Late Amazonian, or several Ma to perhaps ~2 Ga). The cavi unit is sand rich and occurs locally and grades upward and laterally into the PB 1 unit, so there is no unconformity between them. Hundreds of local unconformities occur in the PB 1 unit, particularly in exposures of lower, marginal sequences. PB 2 and 3 units respectively represent relatively lithic- and ice-rich PLD, each no more than several tens of meters thick and superposed on partly eroded surfaces of underlying PB units. Bright residual water ice <1 m thick mostly superposed on unit PB 3 appears to be transient, and its behavior relative to recent climate is under investigation [e.g., 8, 15].

South PLD stratigraphy: The south PLD are made of 4 Planum Australe (PA 1-4) units of Amazonian age underlain by ice-rich Hesperian deposits of the Dorsa Argentea Formation. Each of these PA units are separated by unconformities and made up of meters-thick layers. The PA 4 unit is made up of CO_2 ice, whereas the other units are mostly water ice and dust. Several unconformities of possible regional extent have been mapped in the PA 1 unit. Crater dating of the PA 1 and 2 surfaces indicate that they are likely >100 Ma [16], and their onset could be much older.

Lessons learned: Major depositional breaks occur in both PLD, possibly due to pronounced changes in climate patterns, volatile supply, and other regional to global factors. Because an unconformity occurs just tens of meters below the top of the north PLD [3, 12], attempts to correlate detailed layering signatures below this break among various outcrops as well as to the orbitally driven climate record [1, 2] are highly suspect. Also, significant differences occur in how sequences of north and south PLD are delineated by unconformities. Thus, regional factors may be at play. By extension, other strata on Mars likely face the same obstacles in correlating various outcrops of similar appearance and setting and in constraining their ages.

References: [1] Laskar J. et al. (2002) *Nature, 419,* 375-377. [2] Milkovich S.M. and Head J.W. (2005) *JGR*, *110*, E01005. [3] Tanaka K.L. (2005) *Nature, 437,* 991-994. [4] Fishbaugh K.E. and Hvidberg C.S. (2006) *JGR*, *111*, E06012. [5] Kolb E.J. and Tanaka K.L. (2006) *Mars*, *2*, 1-9. [6] Phillips R.J. et al. (2008) *Science, 320,* 1182-1185. [7] Tanaka K.L. et al. (2008) *Icarus, 196,* 318-358. [8] Byrne S. (2009) *AREPS, 37,* 535-560. [9] Milkovich S.M. et al. (2009) *JGR, 114,* E03002. [10] Perron J.T. and Huybers P. (2009) *Geology, 37,* 155-158. [11] Putzig N.E. et al. (2009) *Icarus, 204,* 443-457. [12] Tanaka K.L. and Fortezzo C.M. (submitted) *USGS SIM,* 1:2,000,000 scale. [13] Salvatore A. (1987) *GSA Bull., 98,* 232-237. [14] Emery D. and Myers K. (1996) *Sequence Stratigraphy,* Wiley-Blackwell, 304 p. [15] Byrne S. et al. (2008) *PSS, 56,* 194-211. [16] Koutnik M.R. et al. (2002) *JGR, 107,* E11, 5100.