MARS GEOLOGICAL PROVINCE DESIGNATIONS FOR THE INTERPRETATION OF GRS DATA.

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Introduction: An overarching geologic theory, GEOMARS, coherently explains many otherwise anomalous aspects of the geological history of Mars [1]. Premises for a theory of martian geologic evolution include: (1) Mars is a water-rich terrestrial planet, (2) terrestrial planets should evolve through progressive stages of dynamical history (accretion, differentiation, tectonism) and mantle convection (magma ocean, plate tectonism, stagnant lid), and (3) the early history of Earth affords an analogue to the evolution of Mars. The theory describes the following major stages of evolution for Mars (from oldest to youngest): **Stage 1** - shortly after accretion, Mars differentiates to a liquid metallic core, a mantle boundary (MBL) of high-pressure silicate mineral phases, upper mantle, magma ocean, thin komatiic crust, and convecting steam atmosphere; **Stage 2**- Mars cools to condense its steam atmosphere and transform its mode of mantle convection to plate tectonism; subduction of water-rich oceanic crust initiates arc volcanism and transfers water, carbonates and sulfates to the mantle; **Stage 3** - the core dynamo initiates, and the associated magnetosphere leads to conditions conducive to the development of near-surface life and photosynthetic production of oxygen; **Stage 4** –accretion of thickened, continental crust and subduction of hydrated oceanic crust to the mantle boundary layer and lower mantle of Mars occurs; **Stage 5** - the core dynamo stops during Noachian heavy bombardment while plate tectonism continues; **Stage 6** - initiation of the Tharsis superplume (~between 4.0 and 3.8Ga) occurs, and **Stage 7** – the superlume phase (stagnant-lid regime) of martian planetary evolution with episodic phases of volcanism and water outflows continues into the present. The GEOMARS Theory is testable through a multidisciplinary approach, including utilizing GRS-based information. Based on a synthesis of published geologic, paleohydrologic, topographic, geophysical, spectral, and elemental information, we have defined geologic provinces that represent significant windows into the geological evolution of Mars, unfolding the GEOMARS Theory and forming the basis for interpreting GRS data.

Geologic Provinces as Windows into the Geologic Evolution of Mars include (mostly from oldest to youngest, as there is overlap of relative age among several of the provinces): (1) the ancient southern highland province - extremely ancient geologic terrains are marked by magnetic anomalies [e.g., 2], especially highlighted in the ancient southern highlands province; other features located in the province include structurally-controlled basins, faults that are tens to thousands of kilometers long, and degraded promontories, many of which are interpreted as silicic-rich volcanoes [e.g., 3] (Fig. 1), similar to geologic terrains of Earth that record plate teconism [4,5], (2) Arabia province records many unique traits, including stratigraphy, topography, cratering record, structural character, geomorphology, and geophysical, elemental, albedo, and thermal inertia signatures, which collectively point to an ancient Europe-sized impact (drainage) basin [6] (Fig. 2), (3) Tharsis rise mountains (Thaumasia highlands and Coprates rise) province (Fig. 3) includes mountain ranges with magnetic signatures that are marked by thrust faults, complex rift systems, and cuestas and hogbacks [7], possibly indicative of a plate tectonic phase during extremely ancient Mars [e.g., 1], (4) Tharsis 1-3 Province (Fig. 4) records the early stages of Tharsis development [8], (5) Hellas-Argyre province (Fig. 5) is void of magnetic anomalies, which indicates that the two impacts post date the termination of the magnetosphere, (6) Tharsis 4-5 Province (Fig. 6) records late stages of development [8], and (7) northern plains (Vastitas Borealis) province (Fig. 7) higlights the Vastitas Borealis Formation that was emplaced during the Early Amazonian [9], possibly related to a Tharsis-induced ocean [e.g., 10].

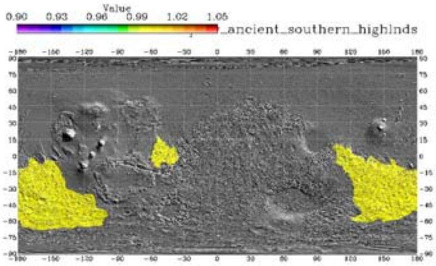

Fig. 1. Ancient southern highlands province (yellow) highlighted on MOLA shaded relief.

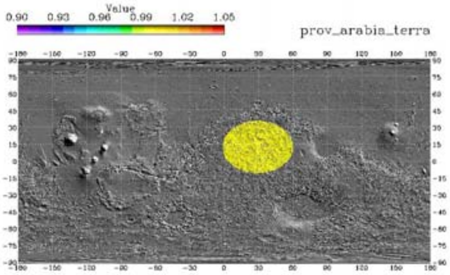

Fig. 2. Arabia province (yellow) highlighted on MOLA shaded relief.

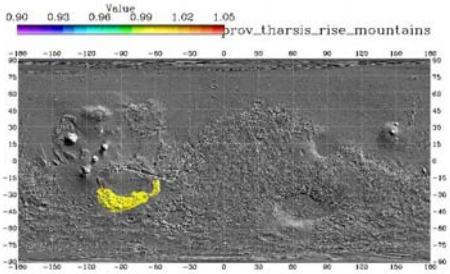

Fig. 3. Tharsis rise mountains (Thaumasia highlands and Coprates rise) province (yellow) highlighted on MOLA

shaded relief.

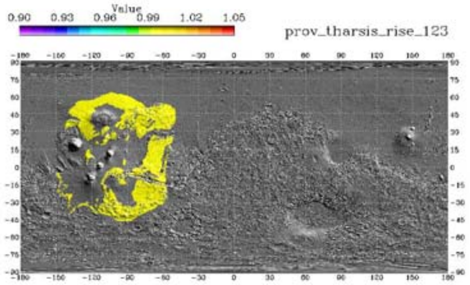

Fig. 4. Tharsis 1-3 province (yellow) highlighted on MOLA shaded relief. Note that 1-3 indicate Stages 1-3 of Tharsis development [8].

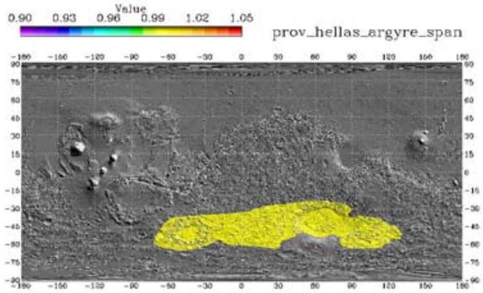

Fig. 5. Hellas-Argyre province (yellow) highlighted on MOLA shaded relief.

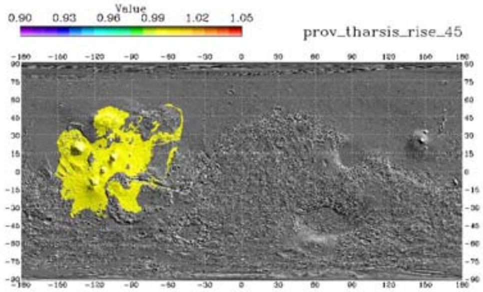

Fig. 6. Tharsis 4-5 province (yellow) highlighted on MOLA shaded relief. Note that 4-5 indicate Stages 4-5 of Tharsis development [8].

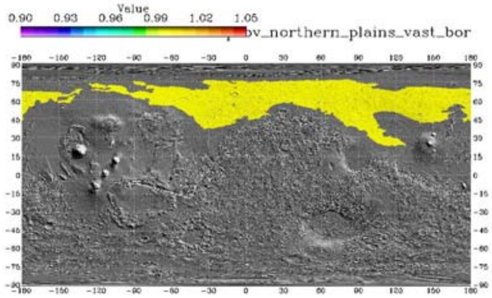

Fig. 7. Northern plains (Vastitas Borealis) province (yellow) highlighted on MOLA shaded relief. Note that the Vastitas Borealis Formation was emplaced during the Early Amazonian [9], possibly related to a Tharsis-induced ocean [e.g., 10].

GRS-based Geochemcial Signatures of the Geologic Provinces: Coupled with other lines of evidence, GRS-based data adds to the assessment of the geological evolution of Mars. Steps taken to perform comparative analysis of the geochemical signatures of the identified geologic provinces include: (1) provinces formatted as bit maps [e.g., 11,12], (2) provinces added to routine whole mission, CO2 frost-free summing and analysis [e.g., 11,12], and (3) spatial and temporal investigation of variation among common elements. A prime example that shows distinctions in elemental abundances among the provinces (others examples will be presented at the meeting) is a GRS-based elemental map showing Cl abundance (Figs 8). Note that elevated Cl abundances is highlighted in the Medusae Fossae region (approximately the yellow highlighted region), which includes the northwestern slope valleys region [13], a region of long-term (Noachian-Amazonian, and possibly present-day) hydrologic, volcanic, tectonic, and possible hydrothermal activity [14].

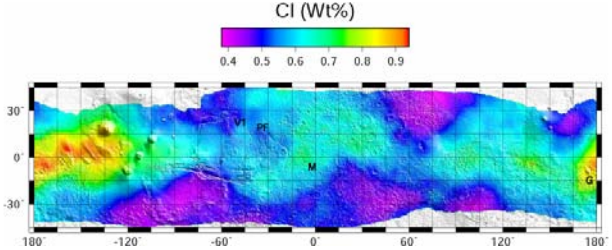

Fig. 8. GRS-based elemental map showing Cl abundance. Note that elevated Cl abundances is highlighted in the Medusae Fossae region, which includes the northwestern slope valleys region [13, 14].

Results: Based on a synthesis of published geologic, paleohydrologic, topographic, geophysical, spectral, and elemental information, we have defined geologic provinces that represent significant windows into the geologic evolution of Mars, consistent with the GEOMARS theory that helps explain anomalies in the geological history of Mars [1]. In addition, GRS data is a key line of evidence in the unfolding of the geologic evolution of Mars, which includes distinct relative elemental abundances among the geologic provinces, especially since GRS can penetrate to a depth of about 0.33 m (e.g., below pervasive thin eolian mantles in many places).

References: [1] Baker, V.R., et al. (2002) Electronic Geosciences 7 (http://lin.springer.de/service/journals/10069/free/conferen/superplu/). [2] Acuña, M.H., et al. (2001) JGR, 106, 23,403-23,417. [3] Scott, D.H., and Tanaka, K.L. (1986) USGS Misc. Inv. Ser. Map I-1802-A (1:15,000,000). [4] Dohm, J.M.et al. (2002) Lunar Planet. Sci. XXXIII, 1639 (abstract). [5] Fairén, A.G. et al. (2002) Icarus, 160, 220-223. [6] Dohm, J.M.et al. (2004) Lunar Planet. Sci. XXXV, 1209 (abstract). [7] Dohm, J.M.et al. (2001) USGS Map I-2650. [8] Dohm, J.M.et al. (2001) JGR 106, 32,943-32,958. [9] Tanaka, K.L. et al. (2003) JGR 108. doi: 10.1029/2002JE001908. [10] Fairén, A.G. et al. (2003) Icarus, 165, 53-67. [11] Boynton, W.V.et al. (2002) Science, 297, 81-85. [12] Boynton, W.V.et al. (2004) Space Science Reviews, 110, 37-83. [13] Dohm, J.M.et al. (2001) JGR 106, 12,301-12,314. [14] Dohm, J.M. et al. (2004) Planetary and Space Science, 52, 189-198.