NON-UNIQUE SYSTEMS OF FEATURES ON MARS AND EARTH: POSSIBLE TELLTALE SIGNATURES OF ANCIENT DYNAMIC LITHOSPHERIC MOBILITY INCLUDING PLATE TECTONISM. J.M. Dohm[1], R.C. Anderson[2], V.R. Baker[3], H. Miyamoto[1], J.-P. Williams[4], G. Komatsu[5], A.G. Fairén[6,7], Y. Jianguo[8], S. Maruyama[9]; [1]Dept. of Space Exploration & Discovery, Univ. Museum, Univ. Tokyo, Tokyo, Japan, 113-0033 (jmd@um.u-tokyo.ac.jp), [2]JPL/California Inst. of Technology, Pasadena, USA, [3]Univ. of Arizona, Tucson, USA, [4]Univ. of California, Los Angeles, USA, [5]Int. Res. School of Planet. Sci., Univ. d'Annunzio, Pescara, Italy, [6]Centro de Astrobiología, Madrid, Spain, [7]Cornell University, Ithaca, NY, USA, [8]Wuhan University, China, [9]Tokyo Inst. of Technology, Tokyo, Japan

Introduction: Prior to the Hellas impact, estimated to have occurred around 4.0 Ga [1], Mars is hypothesized to have had a dynamo/magnetosphere and a global hydrological cycle with an ocean, as well as plate tectonism [2]. Some supportive evidence for this is a systematic, spatial arrangement of landforms of the Thaumasia Plateau and surroundings of Mars, which exhibit a pattern strikingly similar to that of the western United States, including the Colorado Plateau [3] **(Fig. 1)**. We have also identified a terrestrial morphotectonic counterpart to the Colorado Plateau: China's Loess Plateau, which together with the Ordos Basin comprises the Loess/Ordos Plateau (**Fig. 1**). Both the Colorado and Loess/Ordos plateaus having developed in the plate-tectonic setting of Earth, and the similarity in both topographic expression and pattern of landforms between the Colorado Plateau and the Thaumasia Plateau, provide critical corroborative evidence for major dynamic mobile-lithospheric activity. We suggest that the Colorado Plateau and Loess/Ordos Plateau represent morphotectonic manifestations of plate and intraplate tectonism together with associated magmatic-driven upwelling at a long-term, major structural zone of weakness and contrasting crustal/lithospheric conditions (including volatile, temperature, rheology).

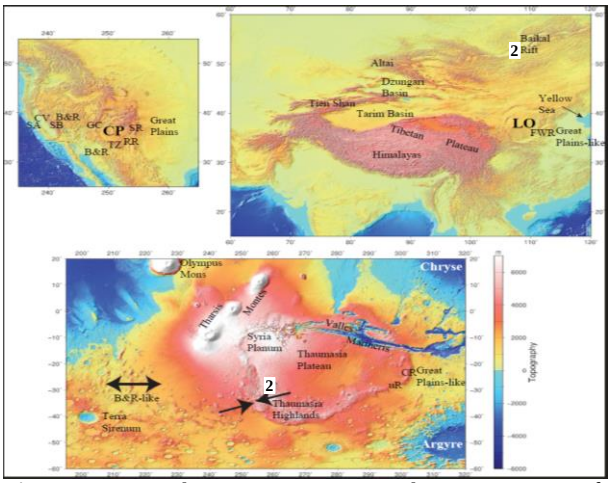

Fig. 1. Topographic maps comparing the arrangement of landforms in the western United States, Earth (**Top left**), with the arrangement in the Claritas Rise and surroundings on Mars (**Bottom;** #2 denotes the Claritas Rise). Shown at a similar scale (**Top right**) is the tectonic setting of the Himalayas and surroundings, including the Loess Plateau/Ordos Basin (LO). The latter has morphological similarities to the Colorado Plateau (CP), including a depressed central core, surrounding mountainous terrain, and a rift system (that cuts the southeast part (Fen Wei--FWR). Also shown are transtensional mountain ranges (the Tien Shan and Altai), the Tibetan Plateau, structurally controlled basins (Tarim and Dzungari), the Baikal Rift (#2 with similar geometric pattern of tectonic structures that cut the Claritas Rise), and great plains. These are all similar to the Martian and terrestrial setting shown respectively at the bottom and top left. Symbol designations include: Southern Rockies (SR), Rio Grande Rift (RR), Transition Zone (TZ), Basin & Range (B&R), Grand Canyon (GC), Sierra Nevada Batholith (SB), San Andreas (SA), and Central Valley (CV), unnamed rift system (uR), Coprates Rise (CR). Diverging and converging arrows indicate respectively interpreted major extension and contraction.

Discussion:

Here we present evidence that extremely ancient Mars (> 4.0 Ga) included manifestations of a dynamic mobile lithosphere based on non-unique features such as the Colorado Plateau, Loess/Ordos Plateau, and Thaumasia Plateau and their surroundings. The two terrestrial examples are the result of plate and intraplate tectonism, plate subduction, and magmatism including upwelling of mantle material. Can a similar tectonic history be ruled out for Mars? Much more research will need to be done to answer this question, including future missions with seismic capabilities. If there indeed was a very early phase of Earth-like plate tectonism on Mars there ought to be:

- Parts of plate boundaries that can be delineated, as first proposed by [4], through careful geological and geophysical investigation. This would include evidence not destroyed by major resurfacing related to the development of the Tharsis Superplume and giant impacts, such as Hellas, Chryse, Isidis, and Argyre, and
- Localities of major crustal shortening, which includes orogenic complexes composed of accretionary complexes, as proposed for the development of the Thaumasia Highlands and Coprates Rise mountain ranges [3,5], including metamorphic belts/serpentine melangés, ophiolites, TTG belts, and volcanic arcs, while in others, mid-ocean-ridge spreading centers.

In our continued geologic investigations of an extremely ancient mobile lithosphere, we are homing in on features of interest, including tectonic structures that may indicate major crustal extension (**Fig. 2**) and shortening (**Fig. 3**), respectively possibly marking Martian spreading centers and trench systems.

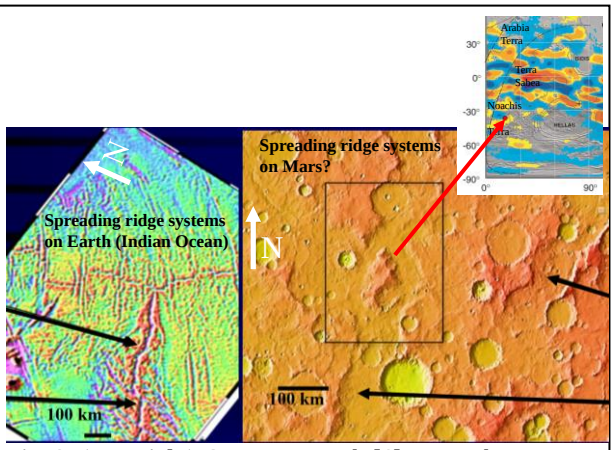

Fig. 2. (**Top right**) Connerney et al. [6] reported two great parallel faults transecting Arabia Terra, Terra Sabea, and Noachias Terra through offset of magnetic contours (**top right**), which they interpret to by transform faults that occur in oceanic crust on Earth, pointing to an early era of plate tectonics on Mars. The red arrow marks the location of the features on the MOLA map at the right-central MOLA map. (**Right-central**) We have identified candidate structural features which could be supportive evidence of this hypothesis. The black arrows point to distinct tectonic structures mapped by [7]; also see Ruj et al. (this conference)] which display a geometric pattern observed at plan view that compares with tectonic features of spreading-ridge systems along the floor of the Indian Ocean as observed on part of a marine gravity map from satellite altimetry based on [8] (**Left-central**); also see http://topex.ucsd.edu/marine_grav/explore_grav.html.

Conclusion: All three plateaus (Colorado Plateau, Loess Plateau/Ordos Basin, and Thaumasia Plateau) and their surroundings suggest that such features are not unique. In the cases of the Colorado Plateau and Loess Plateau, both are the result of terrestrial systems that involve plate tectonism, subduction, intraplate tectonism, and magmatic upwelling at long-term, major structural zones of weaknesses and contrasting crustal/lithospheric conditions (including volatile, temperature, rheology). Whether this includes plate tectonism during Mars' evolution will continue to be investigated. Such future investigation including seismic and sample return missions will test hypotheses such as whether Mars had an extremely ancient phase (> 4.0 Ga) of plate tectonism concurrent with a Martian ocean and relatively dense atmosphere [2] that interacted with a supercontinent (i.e., cratered highlands [9]) composed of felsic- (possibly including granite) and felspathic- (e.g., possibly anorthosite) enriched [10-12] primordial crustal materials through Sun-driven hydrological cycling, conditions of which are referred to as Habitable Trinity [13].

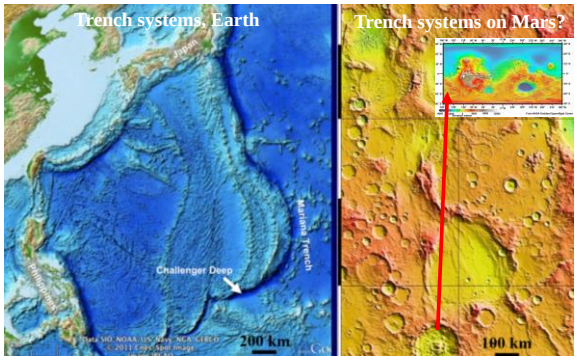

Fig. 3. (**Right**) MOLA map (credits include NASA and Goddard Spaceflight Center) showing a tectonic structure that is more than a thousand kilometers in length among ancient impact craters at the right-central MOLA map. (**Right-central**) Map of the Mariana Trench and surroundings, including the Philippines and Japan (credits include Data SIO, NOAA, U.S. Navy, NGA, GEBCO; copyright—Cnes/Spot Image; Image IBCAO; Data copyright—2011 MIRC/JHA, and Copyright 2010—Google available through press release: 18.03.2013, copyright—Max Planck Institute for Marine Microbiology). Could the major Martian tectonic structure be a marker of major crustal shortening and possibly a Martian trench system?

References: [1] Robbins, S.J. et al. (2013) Icar. 225, 173–184. [2] Baker, V.R. et al. (2007) Springer, p. 507–523. [3] Dohm, J.M. et al. (2015) LPSC 46, Abstract #1741. [4] Sleep, N. H. (1994) J. Geophys. Res. 99, 5639-5655. [5] Anguita, F., et al. (2006) Icarus 185, 331-357. [6] Connerney, J.E.P. et al. (2005) Science 102, 14970–14975. [7] Ruj, T. et al. (2015) Abstract EPSC2015-255. [8] Sandwell, D.T., and Smith, W.H.F. (1997) Science 277, 1957-1962. [9] Spagnuolo and Dohm (2004) Workshop on Martian Hemispheres, Lunar Planetary Institute, Abstract #4001. [10] Baratoux, D. et al. (2014) Workshop on Volatiles in the Martian Interior, Abstract # 1003. [11] Wray, J.J. et al. (2013) Nature Geoscience 6, 1013-1017. [12] Sautter, V. et al. (2015) Nature Geoscience, doi:10.1038/ngeo2474. [13] Dohm, J.M. Maruyama, S. 2014. Geos. Front. 6, 95-101.