RE-ASSESSING PLAINS-STYLE VOLCANISM ON MARS. S. E. H. Sakimoto[1], T. K. P. Gregg[2], S. S. Hughes[3], and J. Chadwick[3], [1]GEST at the Geodynamics Branch, Code 921, NASA Goddard Space Flight Center, Greenbelt, MD 20771, sakimoto@geodynamics.gsfc.nasa.gov, [2]Department of Geological Sciences, The University at Buffalo, State University of New York, 876 Natural Sciences Complex, Buffalo, NY 14260, tgregg@nsm.buffalo.edu, [3]Department of Geosciences, Idaho State Univ., Box 8072, Pocatello, ID 83209, hughscot@isu.edu and chadjohn@isu.edu.

Introduction: The volcanic plains of Mars have long been thought to be analogous to the Snake River Plains (SRP), Idaho, on Earth (e.g. [1-7]), primarily in terms of the range of low shields, fissure eruptions, and flows that coalesce to resurface large tracts of plains regions. The Tempe region of Mars was usually the most frequently cited analog prior to the Mars Global Surveyor (MGS) and Mars Odyssey (MO) missions (e.g., [1, 3-6]). Since the (MGS) Mission and the availability of Mars Orbiter Laser Altimeter (MOLA) topography, it has become clear that the number of shields and vents is far greater than that estimated on the basis of prior image data alone [e.g. 7-9], and that in many cases, the previously identified "shields" (e.g.[5, 6]) were actually only the steeper summits of far more extensive edifices with shallow lower flanks [*7-13*]. Also, while the overall global shield population shows distinct global trends in topographic characteristics with latitude that can be modeled with latitude-dependent availability of water or water ice for hydro-magmatic components of shield formation [7-9]. Since the Martian plains volcanism features have a much larger extent than previously suspected [e.g. 8-10] , and may even be geologically recent [14-16] and are associated in some areas with fluvial and hydrovolcanic features [17-19], the impetus for understanding both Martian plains volcanism and its interactions with water have grown significantly. Here, we are investigating the range of topographic features observed within the SRP in a quantifiable manner for direct comparison to the new Martian data on both a regional and a global basis, with particular attention to topographic/geochemical correlations and parameter characteristics (such as the global flank slope with latitude trends) that can be attributed to interactions of lava and water or lava and ice.

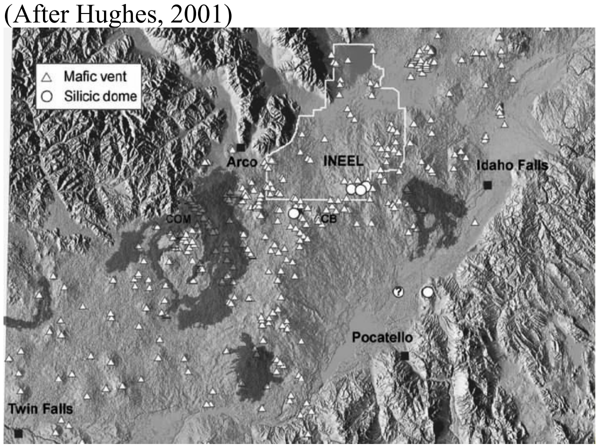
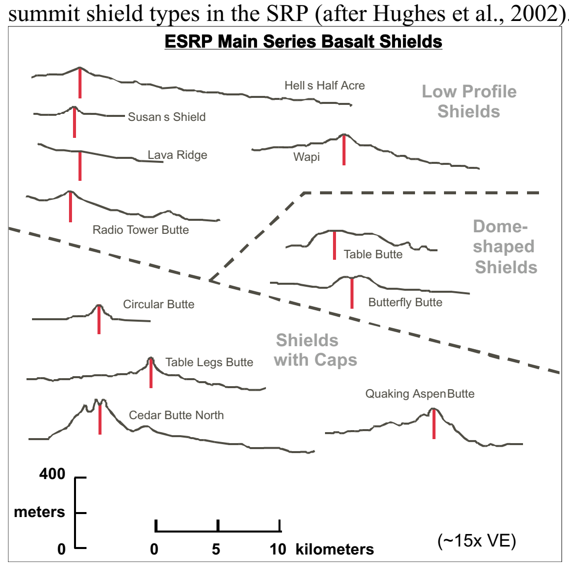


Fig. 1. Shaded relief topography for the with mafic vents and silicic domes indicated. Several of the more recent major flow fields and their extents shown in dark gray. (After Hughes, 2001)

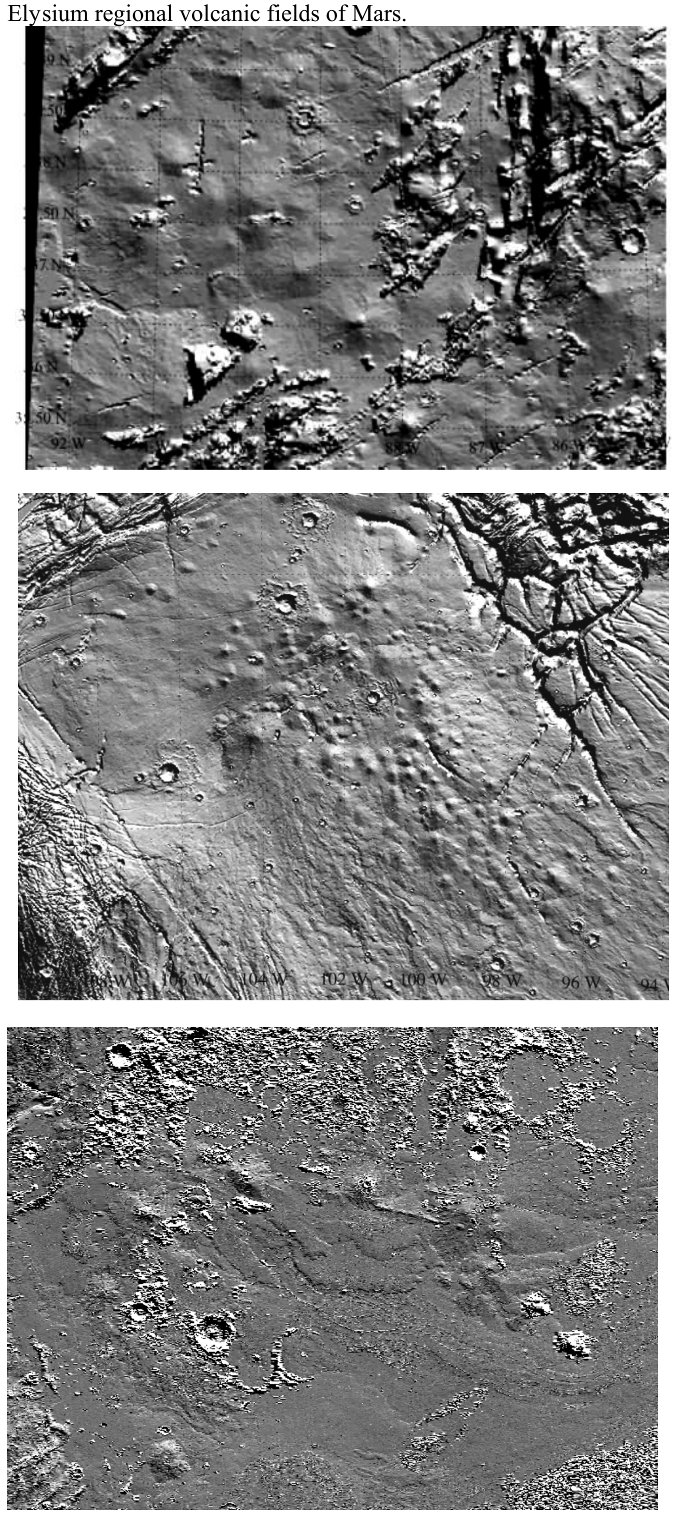
Snake River Plains: Hundreds of small (<5 km basal diameter) monogenetic tholeiitic basalt shields that generated thousands of lava flow units dominate the Quaternary volcanic-sedimentary depositional sequence underlying the eastern Snake River Plain of Idaho [20] (See Figs. 1 and 2). The province is an east-northeast–trending topographic depression, 600 km long and 100 km wide. Commingled lava fields and intercalated sediment compose the upper 1–2 km of the crust. Low-profile basaltic shields with shallowly sloping flanks overlap each other and interfinger with sedimentary deposits to produce a complex, discontinuous stratigraphic sequence. Fig. 2 shows topographic profiles from some of the shield types observed, which range from incipient shields or fissure flow fields to low profile shields to shields with steeper topographic caps to dome shaped shields [7, 19, 21]. Low-profile coalescent shields and the eruptive mechanisms of eastern Snake River Plain basalts reflect the "plains-style" volcanism mentioned above, where low-volume, monogenetic volcanoes form from numerous scattered vents. Each shield on the eastern Snake River Plain

Fig. 2. Examples of low profile, dome shaped and steep summit shield types in the SRP (after Hughes et al., 2002).



formed during a short time period of months or years [20]. The short duration of such monogenetic eruptions may be attributed to a rapid drop in magma pressure due to sluggish crustal response when the source is tapped [20], and petrology suggests that each one probably formed from a series of small individual batches of magma [22-24]. Examination of lavas in the field, using the naked eye and a hand lens, clearly reveal a distinct textural change that correlates with the slope break. Lavas collected from the steep-summit region contain a meshwork of minute plagioclase laths commonly with open spaces between the laths. In contrast, lavas collected from the shallowly sloping lower flanks of Table Butte have few vesicles and fewer phenocrysts. Pinkerton and Stevenson *[25]* quantify the effect phenocrysts have on lava rheology: once lavas contain more than ~25 vol.% phenocrysts, the phenocrysts act to increase lava viscosity. An increase in lava viscosity could explain the steeper summit slopes. Geochemical analyses of the same lavas indicate that those lavas comprising the steep summit regions of the shields with caps (See Fig. 2) are more fractionated than those found on the shallower flanks of the shield. There are no soil horizons or other similar evidence indicating that there was a significant hiatus between the emplacement of the shallowly sloping flank lavas and those erupted at the steep-summit region. We therefore propose that these lavas are the product of a single magma chamber that evolved with time and/or depth. These insights into the magmatic plumbing of small shields could be applied to Mars if we were sufficiently confident in our interpretations of terrestrial volcanic morphologies.

Fig. 3. Shaded relief topography for the Tempe Mareotis, Syria, and Elysium regional volcanic fields of Mars.



Martian Plains: As summarized above, it is clear that the Martian volcanic plains have more readily identifiable volcanic origins and features than was possible before the MGS and MO missions. Fig. 3 shows three examples of volcanic plains regions: Tempe-Mareotis, Syria, and Elysium/Cerberus Rupes. All are now seen to be, with little doubt, of volcanic origins, and we can use the detailed topography to constrain edifice eruption styles, channelized flow rates, and even vent locations [7-13, 17, 19, and others]. Individual volcanic landforms within the plains-style volcanic fields can now be clearly seen in the topography to have a wide variety of landforms, ranging from spatter-rampart-like fissure-fed fields, to low shields, to shields with "hats" or steeper summit areas, as well as extensive sheet channelized, and lava tube flows. It is clear that the relationship between volcanism and subsurface water or volatiles on Mars is both close and perhaps even ongoing, and that topographic data of the volcanic features will be an unprecedented tool and constraint to help determine timing, emplacement mechanisms, volatile interaction, source vents, and the extent of landform types. Fig. 4 shows some of the edifice profiles in comparison to a SRP shield with cap, and Fig. 5 shows both detailed topographic grid and profile data for an example of a Tempe-

Mareotis low shield and shield with a cap. These are clearly analogous to the terrestrial examples shown in Fig. 2, and we are systematically measuring all identifiable small martian shields and the majority of SRP shields for a statistically significant comparison to determine possible geochemical variations.

Finally, Figs. 6 and 7 show some global trends (see [7,8]) for Martian shield data. Some trends (like those in Fig. 6a) can be modeled easily [8] with recently defined near surface global water abundance variations available to eruptions [see 26,27]. Fig. 7 shows preliminary results for the Syria, Vastitas Borealis, and Tempe regions for slope variations as a function of latitude. Clearly, the Borealis region, with its near-pole location has a strong latitude dependence of apparent water interactions, but even the near equatorial features in Fig. 6a show some regional water interaction evidence [18]. Ongoing work within this study will fill in these parameter relationships for each field It is hoped that with new data for both terrestrial and martian volcanic features, the apparent geochemical and water interaction relationships will be better constrained.

Conclusions: Our understanding of Plains-style volcanism is changing for both the terrestrial type locality (SRP) and for Mars. New topographic, geochemical and spacecraft data that combines terrestrial and Martian characterization efforts promises to help constrain not only possibly geochemical variations within regions on Earth and Mars, but also, perhaps, relative degrees of water interactions during eruptions.

Fig. 4. Examples of profiles from (top to bottom), a steep summit shield and a low profile shield in Tempe Mareotis, Mars, an low profile shield in Elysium, Mars, and a steep summit shield in the SRP, Earth.

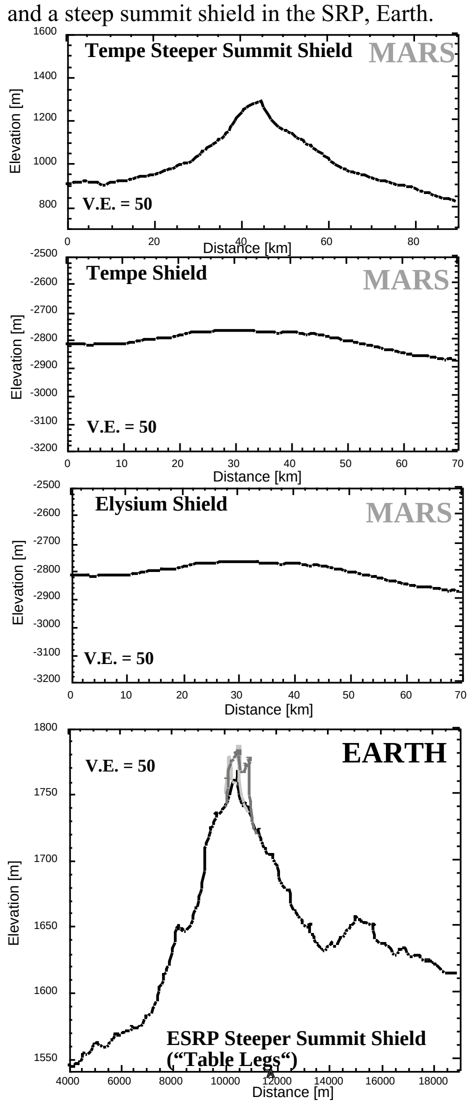


Fig. 5a. Shaded relief topography for a portion of the Tempe Mareotis Examples of a shield with cap (A), low profile shield (B), and a fissure-fed lava field (C).

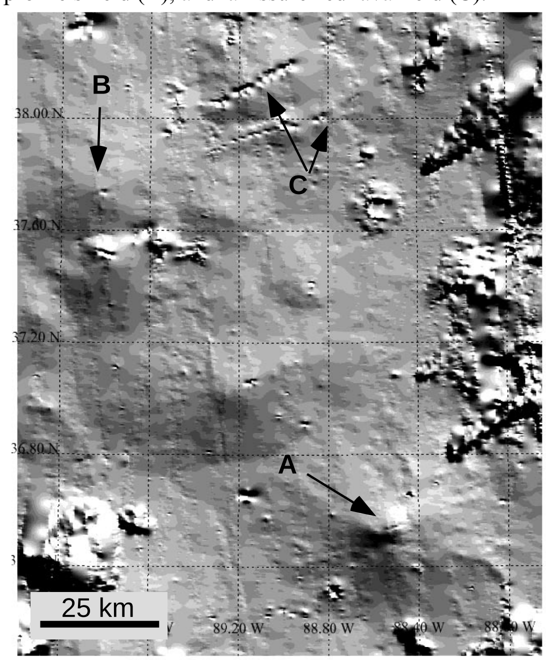
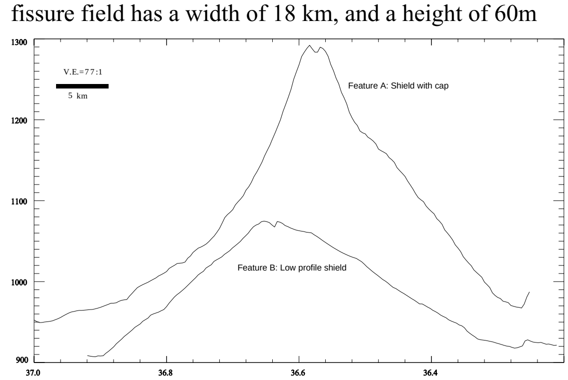


Fig. 5b. Topographic profiles of features A and B. The shield with cap (A) has a basal diameter of 45 km and a height of 330m, while the low profile shield (B) has a basal diameter of 41 km and a height of 70 m. The top fissure field has a width of 18 km, and a height of 60m



References: [1] Hodges C.A. and Moore H.J. (1992) USGS Prof. Paper 1534. [2] Greeley, R. (1977) in R. Greeley and J.S. King, NASA CR-154621**,** 23-44. [3] Greeley, R., JGR 87 (B4), 2705-2712, 1982. [4] Plescia, J.B., Icarus, 45, 586-601, 1981., [5] Davis, P.A., and K.L. Tanaka, LPSC XXIV, 379-380, 1993. [6] Moore, H.J., LPSC XXVI, 993-994, 1995. [7] Sakimoto, et al., LPSCXXXIV, Abstract # 1740, 2003. [8] Sakimoto et al., LPSC XXXIII, CDROM, abstract #1717, 2002. [9] Sakimoto, et al., , Eos. Trans. AGU, 82(47), Fall Meet. Suppl., Abs. P31B-09, 2001. [10] Garvin, et al., Icarus, 145 (June), 648-652, 2000. [11] Wong, et al., LPSC XXXII, CDROM, abstract #1563, 2001. [12] Sakimoto, et al., LPSC XXI, Houston, TX, CDROM, Abstract #1971, 2000. [13] Webb, et al., LPSC XXXII, Abstract # 1145, 2001. [14]Hartmann, W.K., Martian Meteoritics and Planetary Science, 34, 167-177, 1999. [15] Hartmann, and Berman, JGR 105, 15011-15026, 2000. [16] Hartmann, et al.., Nature, 397, 586-589, 1998. [17] Burr, et al.,, GRL 29 (1), 10.1029/2001GL013345, 2002. [18] Lanagan, et al., GRL 28 (12), 2365-2367, 2001. [19] Sakimoto et al., GSA Fall Meeting, Denver 2001 [20] Kuntz, et al. 1992, in Link, P.K., Kuntz, M.A., and Platt, L.P., eds., Regional geology of eastern Idaho and western Wyoming: GSA Memoir 179, p. 227-267. [21] Hughes et al., GSA Fall Meeting, Denver 2002. [22] Hughes, et al., 1999, , in Hughes, and Thackray, eds., Guidebook to the Geology of Eastern Idaho: Pocatello, Idaho, Idaho Museum of Natural History, p. 143-168. [23] Hughes, et al. 2003, in Bonnichsen, et al., eds., Tectonic and magmatic evolution of the Snake River Plain volcanic province: Idaho Geological Survey Bulletin 30 (in press). [24] Hughes, et al. 2002, , in Link, and Mink, eds., Geology, Hydrogeology and Environmental Remediation, Idaho National Engineering and Environmental Laboratory, Eastern Snake River Plain: GSA Special Paper 353, p. 151-173. [25] Pinkerton, H., and R.J. Stevenson, , *JVGR 53*, 47-66, 1992. [26] Boynton, et al., *Science*, *297* (5 July), 81-85, 2002. [27] Mitrofanov, et al., Science, 297 (5 July), 78-81, 2002.

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Fig. 6a. Average flank slope as a function of latitude for small martian shield volcanoes.

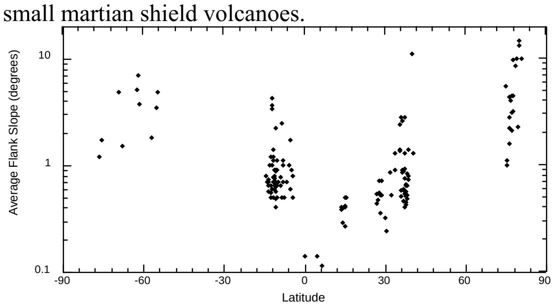

Fig. 6b. Summit crater width as a function of latitude for small martian shield volcanoes.

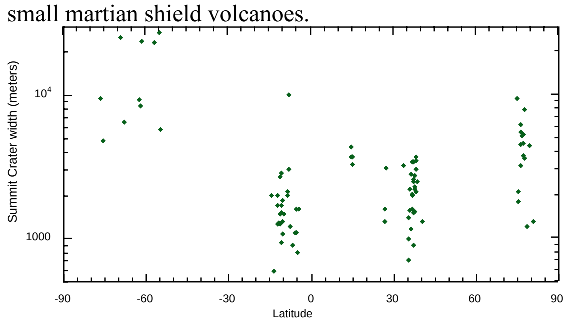

Fig. 6c. Basal diameter as a function of latitude for small martian shield volcanoes.

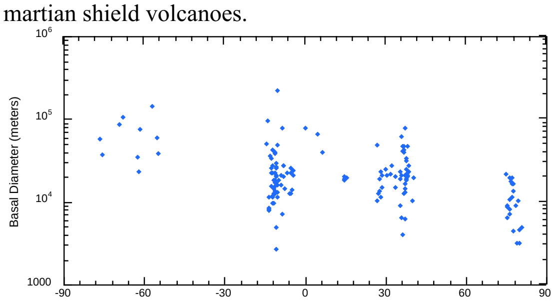

Fig. 6d. Volume/Diameter as a function of latitude for small martian shield volcanoes.

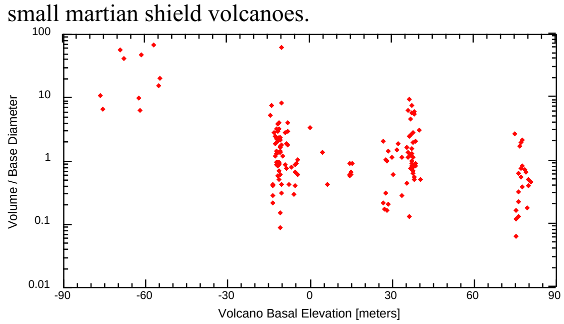

Fig. 7. Examples of regional variations in flank slope as a function of latitude for the Tempe Mareotis, Syria and Vastitas Borealis volcanic fields.