**A PETROGENETIC MODEL OF PLAINS-STYLE LOW SHIELD VOLCANOES ON MARS – IMPLICATIONS FOR MAGMA PRODUCTION IN THE THARSIS REGION.** S. S. Hughes[1], S. E. H. Sakimoto[2], T. K. P. Gregg[3], [1]Dept. of Geosciences, Idaho State University, Pocatello, ID 83209, hughscot@isu.edu; [2]Dept. of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, IN 46556; [3]Dept. of Geology, University at Buffalo, 876 Natural Science Complex, Buffalo, NY 14260.

**Introduction:** Low-volume shield volcanoes are currently recognized in Tempe Mareotis, Syria Planum, and the eastern Tharsis province. Compared to accessible low shields on the eastern Snake River Plain (ESRP) of Idaho, the type locale for plains-style volcanism [1], these low-volume constructs have generated significant interest in the mechanisms controlling the generation of small magma batches and the evolution of resulting monogenetic volcanoes based on comparative analysis to the ESRP system [e.g. 2–11]. In particular, the small-vent fields of the eastern Tharsis province (Fig. 1) are the result of late Amazonian volcanism associated more or less directly with the Tharsis Montes. Small vents in Syria Planum (Fig. 1) indicate earlier Amazonian magmatism; whereas vents on Hesperian terrain in Tempe Terra (Fig. 2) represent the oldest known plains-style vent fields. Because these fields apparently developed in clusters or along alignments [10] and have overall similarities in topography, surfaces and volcanic constructs [4–8], a general petrogenetic model would thus predict mechanisms and scenarios operative in most if not all fields.

**Regional Magmatism:** Tharsis magmatism, especially that which produced the large Tharsis Montes, likely resulted from single or multiple mantle plumes [12–14]. Peripheral magmatism that produced small-vent fields indicates a near-plume magmatic system related to regional extensional stress fields, graben formation and the intrusion of large radial dikes [15–18]. The geologic setting is comparable to the ESRP system [19–21], which developed as a series of eruptive fissures, vent alignments, and clusters of low shields in a post-plume setting responding to regional Basin and Range extension. Dikes swarms and plains volcanism around Tharsis thus reflect multiple intrusions, consistent with prolonged magmatism concentrated along zones of weakness in the crust and a greater extent of thermal demagnetization [22].

**Petrologic Models:** As summarized in detail by McSween [23], source regions of mafic magmas on Earth and Mars (based on basaltic shergottites) are assumed to be similar, although Mars' mantle has higher FeO and density relative to Earth's mantle. Recent Mars crust is essentially basaltic, based on shergottites and other SNC meteorites that likely represent samples of young volcanic centers, such as Tharsis or Elysium [24]. Geochemical and isotopic signatures of shergottites also suggest they derived from mixtures of depleted martian mantle and a late stage liquid trapped in a magma ocean cumulate pile [25], a model that suggests melting of a hybrid source. Decoupled major and trace elements further indicates that any assimilated rock component had a basaltic major element composition [24].

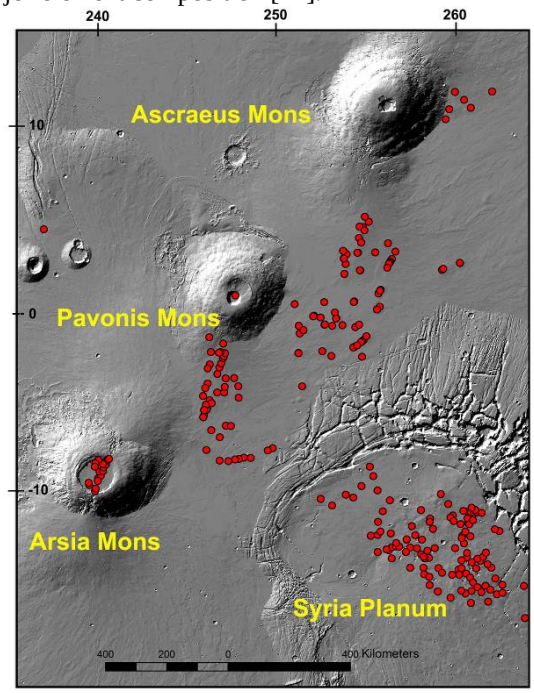


***Figure 1.*** *Map of small shields within and near the Tharsis and Syria Planum provinces based on a shaded relief MOLA image. Sites are identified from MOLA topography, many of which are confirmed by analyzing THEMIS imagery from the exact location. Some vent locations are derived from Bleacher et al. [10] based on HRSC images; however, the dataset will apparently increase as new data from HRSC and HiRISE are obtained and evaluated.*

Geochemical analyses of ESRP basalts [20, 21] indicate two petrogenetic lines and possibly multiple magmatic sources based on large variations in major and trace elements without appreciable isotopic variability. Parental liquids with high MgO and low incompatible elements (MgO ~7.5 – 11.2 wt. %; La ~7 – 19 ppm; Ba ~100 – 290 ppm) follow ol ± pl fractionation paths, while evolved compositions (MgO ~ 4.6 – 8.6 wt. %; La ~18 – 68 ppm; Ba ~250 – 820 ppm) follow linear mixing trends [26]. Evolved chemical trends are modeled by two component mixing of high-Mg parental magmas with low-Mg liquids in the middle to lower crust (Fig. 3). Low-Mg endmember liquids are

either residual melts generated by extreme crystallization of mafic magmas, or they result from small degrees of melting of mafic intrusions. This model is compatible with the emplacement of mafic sills in the ESRP system [27], which provides a source for low-volume batches of variably evolved magmas derived from a range of crustal depths [26]. The model further implies that a similar scenario can be used to base models of low-shield magmatism on Mars and perhaps extended to basaltic shergottite petrogenesis.

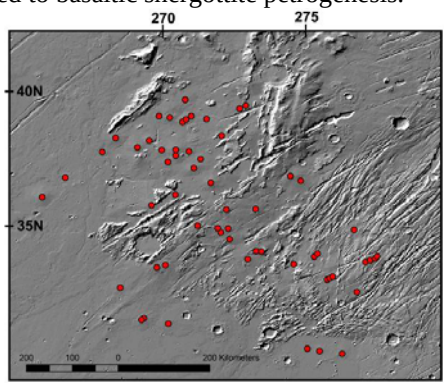


***Figure 2.*** *MOLA shaded relief map of small vents in the Tempe Mareotis region.*

**Implications for Tharsis Magmatism:** Without direct sampling of low-shields on Mars only a general petrologic model is possible. However, the two-component mixing model and apparent requirement for low-volumes of magma production, suggest that the low shield fields in the greater Tharsis region, as in the ESRP, are generated in response to multiple injections of primary magma and the development of a regional sill network. A near-plume (or post-plume) setting is appropriate to establish thermally-weakened and demagnetized [22] lithospheric conditions in response to lateral spread of an impinging mantle plume and magma intrusions. The lithosphere would then become thermally capable of piecemeal magmatism in response to regional extension, thereby establishing linear eruptive fissures and graben networks [10,16].

More importantly, the ESRP trace element trends reflect variable mixing between enriched and depleted (or primitive) components in hybridized source regions, as predicted for shergottite petrogenesis [25]. Also the model predicts that each shield is derived from a separate magma batch, producing large variations in geochemical signatures representing primary and evolved compositions.

Tests for geochemical enrichment and variability in low shields on Mars could be used to confirm or deny this hypothesis. Low shields in the Tharsis region could be targets to evaluate possible geochemical enrichments due to serial magmatism and mixing.

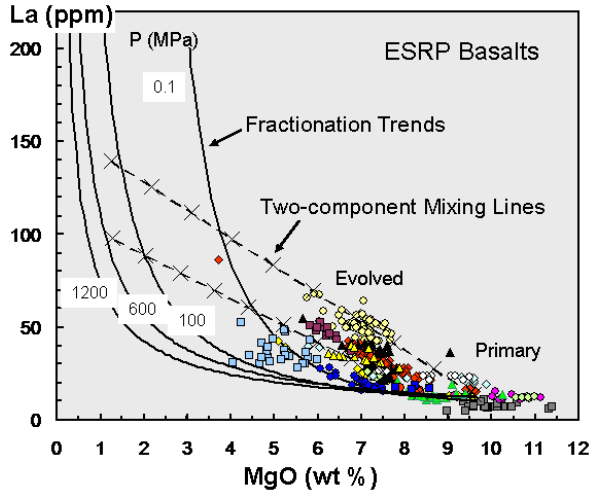


***Figure 3.*** *Example of two-component mixing model for ESRP basalts [e.g., 8, 21, 26].*

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