THE GALAPAGOS AND HAWAII VOLCANOES: TWO ANALOGS OF SYRIA PLANUM ON MARS.

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Introduction: Studies of terrestrial volcanoes can be used to interpret the styles of volcanic processes and the evolution of volcanic systems on Mars. Detailed characterizations of terrestrial flow fields provide critical evaluation of flow field emplacement on planetary surfaces, such as vent fissure type features associated with volcanic shields eruptions that help characterize long-term planetary flow fields. Here we compare three well developed volcanic systems: The Western Galapagos and the Kilauea, Hawaii terrestrial volcanic systems with the Syria Planum volcanoes on Mars. [1] used several datasets to describe the tectono-magmatic evolution of Syria Planum, including high spatial and/or spectral resolution, such as High Resolution Stereo Camera (HRSC) imagery from the Mars-Express spacecraft, Thermal Emission Imaging System (THEMIS) data from the Mars Odyssey Mission, High Resolution Imaging Science Experiment (HiRISE) imagery from the Mars Reconnaissance Orbiter and Mars Orbiter Laser Altimeter (MOLA) data. Comparison with the terrestrial study proposed here will allow us to better assess the rheological properties of the flows, the relation and timing of several eruptive periods, and provide us an estimate of the depth of the associated magma chambers. This study will establish the eruptive and emplacement history of the larger shield volcanoes and volcanic provinces found on both Mars and the Earth.

Kilauea volcanic system: Several flows were emplaced during the 1970s and 80s along fissures in the Southwest Rift Zone on the Big Island of Hawaii. However, the most predominate lava flow field is associated with Mauna Iki, a small satellitic shield volcano on the western flank of Kilauea that erupted from December 1919 to August 1920. It has been observed that radially placed satellitic shield eruptions on Kilauea, Hawaii contribute significantly to the growth of the volcano and are likely associated with lava tube systems and long duration eruptions [2]. Of the 15 satellitic shields on Kilauea [3], Mauna Iki and two others formed in historical times, including Mauna Ulu in 1969-1974; and Kupanaiaba in 1986-1992. The relationship between activity at the summit of Kilauea and downrift provides important information for understanding the connections (hydraulic or otherwise) between the summit and rift zones of Kilauea as well as information concerning the depth of the magma chambers and the lava conduit system (see detailed information on Table 1). The distributary lava system in the Hawaiian volcanoes is not dense, although it appears to transport significant volumes of lava - southward - given the lengths of the flows and the number of associated breakouts and levee systems that usually contain large zones with slabby and clinkery lava textures, commonly found along flow fronts and margins. This type of information permit us understanding the emplacement history of the lava and the evolution of the volcanic system.

Syria Planum volcanic system, Mars: Syria Planum is a broad volcanic plateau located at the summit rise east of Tharsis (> 6 km high above MOLA datum). The plateau of Syria Planum is ~ 450 by 700 km wide, and is centered at 12ºS; 104ºW. According to [1], it is possible to constrain the formation of Syria Planum to successive magmatic and tectonic events, from the Early to the Late Hesperian period: I) extensional field stress that produced grabens; II) eruption of Syria Mons resulting in lavas that spread across Syria Planum; III) tectonic deformation of the emplaced lava flows by the formation of several fractured patterns such as NE-SW enechelon faults, troughs and adjacent grabens; and IV) new episodes of volcanic activity, forming coalesced small shield swarms (SSV) that bury preexisting faults. Syria Planum shield volcanoes played an important role in the primordial Tharsis Province volcanism, but their activity ceased in the Hesperian [1], early in the geologic history of this region. The progressive cessation of activity might have been due to the enhanced crustal thickness in the magmatic processes of this region.

The Galapagos Volcanoes: The Galapagos Archipelago is a group of volcanic islands near the Ecuator. The volcanoes are believed to have grown above a hotspot on the south side of the East-West trending Cocos-Nazca spreding center [4]; the hotspot is now apparently centered under Fernandina and Isabella Islands. At least eight volcanoes have erupted historically [5]. Here we focus on the Fernandina and Isabella Islands, which make the western group of volcanoes (Fernandina - F, Wolf - W, Darwin - D, Alcedo -A, Sierra Negra - SN and Cerro Azul – CA) (see Table 1 for detailed description of each volcano). All of these volcanoes are basaltic shields with large summit calderas, and mostly erupt lavas from linear to arcuate eruptive fissures, circumferential on the top of the caldera and radial lower on the flanks. The pattern of eruptive fissures reflects the orientation of underlying dikes intruded from magma reservoirs beneath the calderas. This pattern is intriguing because it is rare on other basaltic shields on Earth, and has thus inspired a lot of speculation about its origin and significance.

Here we propose a planetary analog for this system: the Syria Planum on Mars.

The Young Galapagos Volcanoes in comparison with Syria Planum on Mars (see details in Table 1 and Figure 1): The geomorphological characteristics of the lava flows analyzed in Syria Planum consistently change where the underlying slope changes [1]. This means that the regional slope is an important factor for controlling the morphology of the Syria Planum flows. These characteristics are consistent with high effusion rate volcanic systems that typically involve low viscosity lavas [6]. This situation is also observed in the Galapagos Islands (e.g. [5]) where the major factor controlling volcano morphology is the small volume of flows that erupted from the summit, while those that erupted near the break-in-slope at the base are more voluminous. This provides some clues for explaining the circumferential fracturing pattern existing around the Syria Mons that alternate with fractures radial to the Eastern Syria swarm of smaller shields (SSV) [1].

Moreover, several collapsed features were identified in the vicinity of Syria Mons, indicative of the numerous subsidence events that occurred over time; perhaps a consequence of the lavas deposition and deflation. These collapse features postdate all other terrains of Syria Planum, and they also affect the SSV in their northern boundary. This pattern of multiple collapses around the main caldera is also seen on the volcanoes of the Galapagos Islands [2] and seem to be in response to a stress regime created by subsurface dike propagation, which allows continued development of arcuate fissures, circumferential to the volcano's caldera [4]. This unusual pattern of eruptive fissures is very distinctive in the Galapagos Islands, although rare elsewhere on Earth [7], and it is still unclear why and how they form [4]. In analogy to what is observed in Syria Planum, we propose that in the Galapagos Islands the eruption focus may have migrated either southward around the volcano forming the long lava flows (over the steeper slopes) and then northward forming small shield volcanoes or smaller volume lavas. This suggests that the eruption may have occurred through different dike intrusions over time.

Conclusions: The eruptive pattern of lava flow features and low shield volcanoes similar to those found in the Kilauea volcanic system of Hawaii and in the Galapagos Islands are found in one particular region on Mars: Syria Planum, near the Tharsis Montes. Kilauea and its satellitic system, the radial rift structures, and development of the volcano southward, is a good analog for interpreting the volcanic activity associated with satellitic shield eruptions on Mars, such as the SSV in Syria Planum, suggesting that migration of the magma source occurred over time. The circumferential pattern of faults localized around the larger calderas and that frequently extend radially down the flanks on Galapagos Islands is also observed around Syria Mons on Mars, suggesting different dike intrusions over time.

References: [1] Baptista et al. (2008) *JGR,* **113**, E9. [2] Rowland and Munro (1993) *Bull Volcanol*, **55**, 190-203. [3] Holcomb (1981) *Ph.D. Thesis Stanford Univ., CA*. [4] Chadwick and Howard (1991) *Bull Volcanol*, **53**, 259-275. [5] Simkin (1984) *Pergamon Press, Oxford*, 15-41. [6] Gregg and Fink (1996) *JGR*, **101**(E7), 16891-16900. [7] Geist et al. (2006) *Geochem. Geophys. Geosyst.*, 7, Q12007.

Table 1. Comparative description of the Galapagos, Hawaiian Kilauea and Syria Planum- Mars volcanic systems.

	Galapagos F; C; W – D; S; A		**Hawaii Eg:Loa -Kilauea**		**Syria Mons - Mars**	**Syria Small Shields -Mars**
Volume of supply lava	Less volume	More volume	High volume	?	Less volume	Higher volume
Seafloor	Young		Old and thick		Thick but didn't last more than 0.5 Ga	
Upper flanks	High – Summit vents build a steep central carapace surmounting gently dipping lower flanks derived from voluminous flows from radial vents.	Low- With radial vents on the flanks that produce a wide, flat shield	Low – constructed on the sloping flanks of older volcanoes which facilitates linear rift formation parallel to the flanks.		Higher: > 1º	Low: < 1º
Caldera shape						
Magma chamber	Funil shape (diapiric)	Larger and wider	Larger/wider		Funil shape	Larger/wider
	Beneath the center of the volcano		?		Beneath the center of the volcano	Placed far from the center
Subsidence events	Higher subsidence	Limited subsidence	?		Higher subsidence	Limited subsidence
Faults	Presence of arcuate features around the volcano	Less arcuate features	Radial to volcano and grabens - except for Kilauea – some arcuate fissures		Presence of arcuate features visible E and SE of the volcano (inferred circumferential pattern)	Radial to volcano - Grabens also present
Eruptive features	circumferential	circumferential+ radial	radial		circumferential+ radial	radial
Caldera/ Volume of lava	Larger size/ Low volume		Smaller size/High volume		Larger size/ Low volume	Smaller size/High volume
Type of lavas	- No/few pahoehoe tub-fed lavas - More a'a lavas « high effusion rates		- Well developed tub-fed pahoehoe + a'a « Mix		- Mix of pahoehoe and a'a « Mix	Predominant a'a lavas « high effusion rates

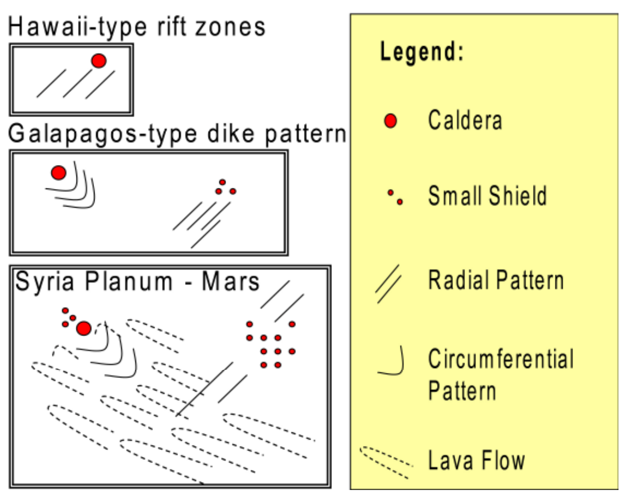

Figure 1. Schematic Ilustration of the three volcanic systems analysed here.