PIT CHAINS ASSOCIATED WITH RADIATING GRABEN-FISSURE SYSTEMS ON VENUS: FORMATION DURING LATERAL DYKE INJECTION?

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Introduction: Pits are circular to elliptical, steep-sided, flat-bottomed depressions interpreted to form from collapse into a cavity. They occur on Earth, Venus and Mars [1-3] and range in diameter from ~100 m to several kilometres. Pit chains are linear successions of pits that can extend from hundreds of metres to tens of kilometres in length and contain varying numbers of pits.

Pit chains on Venus are typically aligned in the same direction as other adjacent linear features, primarily graben-fissure systems, which suggests that there is a causal relationship between pit chain formation and the presence of the dykes thought to typically underlie graben-fissure systems [4-6]. The goal of the present study is to gather further evidence for this genetic link, based on the surface expression of pits and pit chains. In this study we focus on pit chains related to radiating graben-fissure systems. In radiating graben-fissure systems [4-6], dyke injection direction is laterally away from the system's centre, so any progressive changes in pit and pit chain properties moving outward from the central area could reflect changing conditions during lateral dyke propagation.

Methodology and study area: Using the 75 m resolution Magellan mission SAR images, 64 pit chains associated with radiating graben-fissure systems belonging to the Kono Mons (91.8˚W, 19.0˚N; diameter ~900 km) and Theia Mons (79.721˚W, 23.641˚N; diameter ~1150 km) radiating systems were mapped and characterized, and preliminary observations are summarized below (Fig. 1 and 2).

Observations:

New pit chain classes. Venusian pit chains have been classified based on the size and arrangement of their pits into 3 categories: discontinuous pit chains, trough pit chains, and tadpole pit chains [1-3]. Additional pit and pit chain classes are recognized in the present work: "pit pods" (successive equally-spaced pits of the same size exhibiting a slight curvature) (Fig. 2A), teardrop-shaped pits (Fig. 2B), and pit fields (large, non-linear clusters of pits at relatively close proximity to the radiating centre) (Fig. 2C).

Variations in pit chain characteristics with distance from the centres of radiating graben-fissure systems. In the Kono Mons area, the greatest abundance of pit chains is between 150-200 km from the radiating centre (Fig. 1A). Similarly, pit spacing and diameters have maximum values between 150-200 km and decrease with increasing distance.

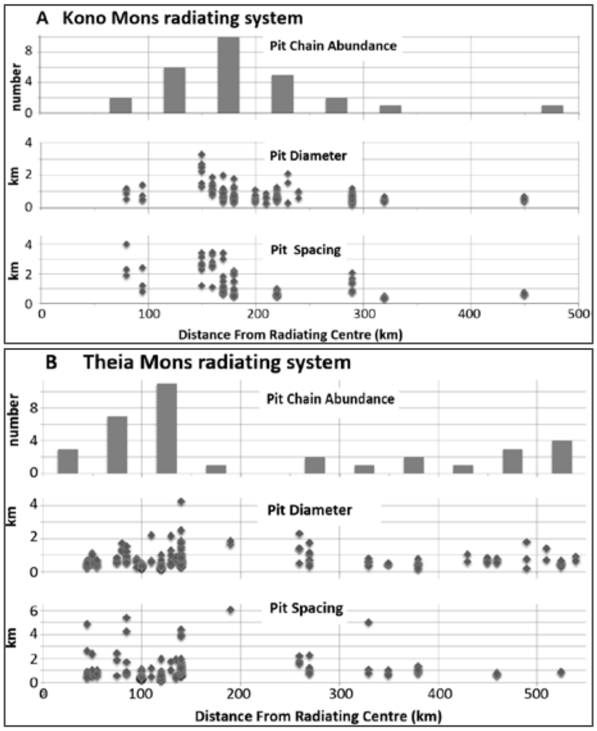

Figure 1: Variation in pit chain abundance, pit diameter and pit spacing with distance from the radiating centre. A) for Kona Mons, B) for Theia Mons.

In the Theia Mons area, the largest concentration of pit chains is between 100-150 km from the radiating centre, after which the abundance of pit chains is relatively constant from 250 to 550 km. The near absence of pit chains between 150 and 250 km is explained by local volcanic flooding.

Both in Kono and Theia areas, pit diameters show a large range of values at any distance. These values reach an average maximum at a distance of ca. 150 km for both Kono Mons and Theia Mons. There is an increasing trend in both systems moving away from the radiating centre to their respective maximums, and moving further outward from this point, a gradual decreasing trend can be identified. Pit spacing data is much more scattered and does not appear to show the same trends.

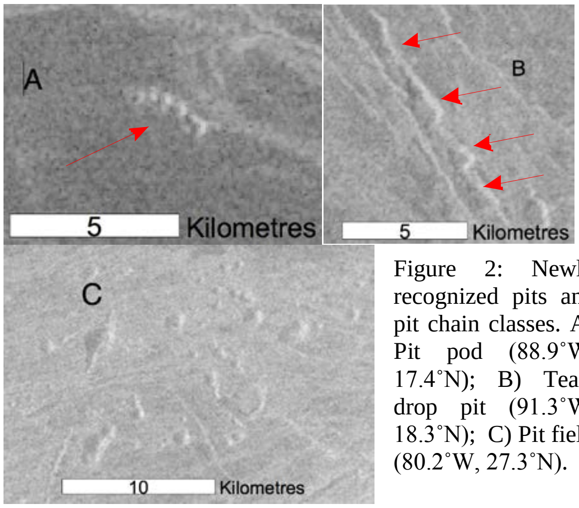

Figure 2: Newly recognized pits and pit chain classes. A) Pit pod (88.9˚W, 17.4˚N); B) Teardrop pit (91.3˚W, 18.3˚N); C) Pit field (80.2˚W, 27.3˚N).

Discussion:

Pit Chains and Dyke Propagation. The preliminary observations from the two radiating systems considered, show a greater abundance of pit chains and also a maximum in pit diameter at similar relative distances (with respect to the systems' sizes) from their respective radiating centres. This is not observed in the pit spacing data, which exhibits a large variability. Systematic trends outward from the radiating centre are provisionally interpreted to be correlated with the propagation of underlying dykes. Additional mapping of pit chains in other radiating systems is required to validate this correlation.

Pit Chain Formation. Various general models of pit formation have been proposed (e.g. [7][8]). The present study considers the hypothesis that pits form in association with active lateral dyke propagation. In order to create a pit, a cavity must be created in the subsurface for the overlying host rock to collapse into, which implies that the dyke must be propagating at shallow depths and the overlying host rock must be friable. A possible model (Fig. 3) was constructed by incorporating constraints on the mechanics of dyke propagation [9][10] and observed pit morphologies.

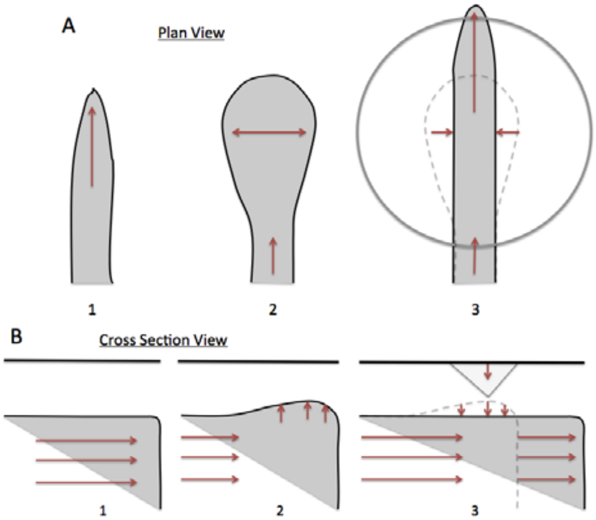

Figure 3: Model of formation of a collapse pit above the leading edge of a laterally propagating dyke that has discontinuous movement. Each time forward movement (step 1) is stopped (step 2), then magma pressure builds up and the dyke width and vertical height increase (and potentially causes some fragmentation of the overlying rock). Then the tensile strength of the rock is exceeded and the dyke resumes forward propagation (step 3). At this point the vertical height decreases and a gap is produced into which the friable overlying layer collapses forming a pit (large circle-A, downward triangle-B). Repetition of this process of stopping and starting of the dyke produces a pit chain.

Stopping and starting of the dyke's propagation could be the result of the dyke's magma pressure being unable to overcome the tensile strength of the host rock. This may be due to changes in the magma supply, where a decrease in magma supply causes the dyke to halt and then advance again when magma supply resumes. Another possibility is that magma supply is continuous but the pressure is below that required for propagation; only when pressure builds sufficiently can the dyke advance before halting again as the pressure drops back to ambient levels. This is a cyclical process.

References: [1] Bleamaster, L.F., Hansen, V.L., (2001) LPSC XXXII, #1316. [2] Wyrick, D.Y., et. al., (2010) LPSC XLI, #1413. [3] Davey, S.C. et al. (2013) Can. J. Earth Sci., 50: 109–126. [4] Grosfils, E.B., Head, J.W., (1994) GRL, 21, 701-704. [5] Studd, D., et. al. (2011) Icarus 215, 279-291. Ernst, R.E., et. al., (2003) Icarus 164, 282-316. [7] Smart, K.J., et. al., (2011) JGR 116, E04005. [8] Wyrick, D.Y., Ferrill, D.A., (2004) JGR 109, E06005. [9] Rivalta, E., et. al., (2015) Tectonophys. 638, 1-42. [10] Rubin, A.M., (1995) Ann. Rev. Earth Planet. Sci. 23, 287-336.