THE KUANJA/VIR-AVA CHASMATA: A COHERENT INTRUSIVE COMPLEX ON VENUS.

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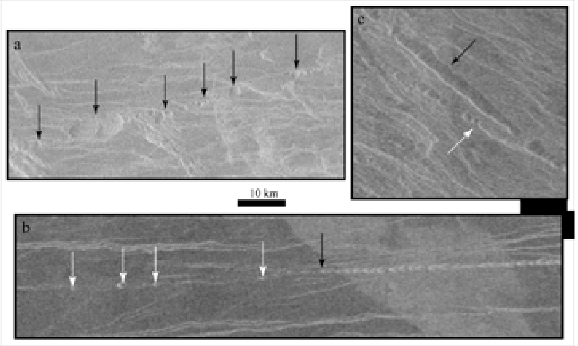
Introduction: Chasmata on Venus are zones of deformation ranging from 150 kilometers to over 400 kilometers in width and have varying lengths typically on the order of 1000's of kilometers. Structural mapping within the Kuanja and Vir-Ava chasmata complexes has led to the identification of particular E-W trending suite of lineaments (pit chains and narrow troughs) that represent arrested dikes at depth. The presence of these structures and their spatial association with other volcanic features suggests that the chasmata is a "coherent intrusive complex."

Chasmata Structures: Pit chains are linear collections of individual pit craters (circular to elliptical, shallow, steep-sided depressions reminiscent of caldera-like collapse features). The chains range from 10's to 1000's of kilometers in length and have widths ranging from 10 kilometers down to the resolution of the radar (~75 m). Radar interpretation of pit chain morphology is facilitated by the accentuation of the steep, radar-facing, interior, scalloped wall. The pit chains are generally straight but have minor undulations along their trend, typically in response to nearby topography. For classification purposes we separate pit chains into three morphologies: 1) discontinuous pit chains, 2) linked pit chains, and 3) linked pit chains with outflow channels. Discontinuous pit chains (a and left b) consist of variably-spaced, individual pit craters (differing in diameter) aligned with one another. Linked pit chains (right b) exhibit the same linearity as discontinuous pit chains, but the individual pit craters have coalesced into one uninterrupted, scalloped-walled trough nearly constant in width. The third morphology is a linked pit chain with outflow channels. A breach in one of the walls of the pit chain allows lava to flow from the structure, generating a channel capable of transporting lava 10's to 100's of kilometers away. Differences in these morphologies may reflect differences in magma volume, depth to the magma source, or velocity of magma flow. Terrestrial examiners have related pit chain formation to the intrusion and flow of magma through fractures resulting in stoping of the roof rock followed by collapse [1].

Troughs, like pit chains, in the Kuanja/Vir-Ava chasma region trend approximately due E-W. They have lengths of 10's to 1000's of kilometers with widths generally greater than 5 kilometers. The troughs are wider than most pit chains and typically have straight margins; however, some exhibit scalloped margins and appear to be pit chains that have experienced enhanced wall collapse. Troughs with this appearance typically taper and merge into pit chains along their trend (c). Within the Kuanja/Vir-Ava structural suite, straight-margined troughs and discontinuous pit chains represent two end member morphologies, whereas linked pit chains and scalloped troughs come somewhere in between. The overall similarities of their morphologies and the transition from one type of structure to the other along their trends suggest that a similar process(es) is responsible for their formation.



In addition to troughs and pit chains, normal faults are located on the north and south flanks of the chasmata complex. They are 100's of kilometers in length and help to accommodate the near 4 kilometers of topographic relief. Faults of both the northern and southern flanks truncate and offset pit chains and troughs, indicating that they locally postdate both types of structures. The normal faults also merge into pit chains and troughs, suggesting that the faults follow weaknesses imparted to the crust by the earlier structures.

Troughs and Pit Chains, Dikes at Depth: Numerous terrestrial "coherent intrusive complexes" have been identified and studied in Hawaii and Iceland [2,3,4]. The surface expression of such an intrusive complex is a rift zone; one specific rift described by Walker is characterized by 5-20 kilometer-wide and 40-100 kilometer-long swarms of tension fractures, normal faults, and volcanic fissures. Characteristically, the intrusions within a rift are tightly packed bladed dikes with sub-parallel trends whose intrusion density falls to near zero at the flanks of the complex. In addition, many volcanic complexes have central volcanoes and collapsed calderas [5]. Of particular importance is the recognition of numerous dikes that arrest at depth (up to and greater than 40% intrusion density) in terrestrial complexes [6].

Prior to solidification, dikes serve as channels for magma flow. Magma can travel from a supply chamber through dikes to the surface where they feed surface lava flows. However, if magma supply rates decrease or the dike enters crustal layers where the dike-normal compressive stress exceeds the magmatic excess pressure, the dike may arrest [7,8]. Despite the mechanism responsible for arrest, the potential for dikes to never reach the surface is significant. Within the past 20 years, descriptions and models of terrestrial dikes by a number of authors [1,4, 9,10,11] have determined that arrested dikes have a surface signature. These authors recognize that the surface manifestation of individual dikes at depth are troughs and pit chains at the surface; similar descriptions have been made for radiating dike swarms on Venus [12,13,14,15] and Mars [16,17]. Geometric, geomorphic, and geologic characteristics of the troughs and pit chains support the dike at depth interpretation. Outlined below are some of the observations made that support our interpretation of these structures.

Linearity. Both troughs and pit chains within the chasmata trend E-W with minor undulations along their lengths due to local topographic fluctuations. The extreme lengths (~2000 km) of the structures with near constant orientation (and their variability due to local effects) suggest that their orientations are governed by the regional and local lithospheric stress field, rather than local surface slope variations. This, in turn, suggests that the observed surface structure (trough or pit chain) formed as the result of a process occurring at depth (dike intrusion) and not by surface processes (e.g., lava tubes, because lava tubes flow under the influence of gravity and in a direction that reflects the local topographic slope). Trough and pit chain orientations within Kuanja/Vir-Ava are not consistent with surface flow structures. However, lava flows and channels emanating from within the troughs and pit chains do exhibit surface flow morphologies.

Lack of periodicity. The troughs and pit chains of Kuanja/Vir-Ava have generally a Gaussian-type spatial distribution with no recognizable periodicity. Periodic or regular spacing of fractures and faults is common and is generally attributed to strain shadowing near pre-existing structures. Faults and fractures, representing free surfaces which cannot transmit stress [18], seem to be able to "see" each other and individual structures accommodate strain until stress levels can no longer be supported by the particular structure. Subsequently, new structures form at intervals dictated by the physical properties of the material and therefore become periodic with increased amounts of strain [19]. Dikes, however, only represent free surfaces for the period of time that they are molten. Once dikes solidify, they no longer "see" each other and may intrude entirely independent of one another. The result could be a dike complex that has a high intrusion density near the magma source and decreasing density with increased distance from the source. Recent dikes also may show crosscutting relations with older dikes. Therefore swarms with high intrusion densities may have anastomosing characteristics. The anastomosing nature of the dikes would therefore also be reflected in any surface features that form in response to their intrusion.

Volcanic associations. The Kuanja Chasma defines a limited zone of deformation and volcanism. The spatial and structural associations of troughs and pit chains with other volcanic features within the chasmata strengthen the arguments for their representation as dikes at depth. Small volcanic flows that emanate from within the structure are associated with troughs and pit chains. Central volcanoes and calderas are located near the center of the chasmata; these features represent potential sources of magma for dike formation. In addition to the caldera there is a set of circumferential dikes (troughs) around the caldera. Gudmundsson [5,8] has commented on features with similar geometries in Iceland's volcanic rift zones. They are sheeted or cone dikes that form when the magma supply rate, from a central magma chamber in the rift, exceeds the rate of lateral space accommodation due to local mid-ocean-ridge spreading. The variability in spreading rate and magma supply creates transitions from lateral to vertical magma migration, resulting in different but predictable dike geometries. A lack of significant lateral mobility of the Venusian lithosphere makes the formation of sheeted dikes around a central magma chamber on Venus reasonable to hypothesize. Linear, laterally propagating dikes give way to circumferential, vertically propagating dikes when horizontal dilation of the crust has reached its limits.

Conclusion: Any comprehensive explanation of chasmata processes must acknowledge the presence of pit chains, troughs, normal faults, calderas, central volcanoes, lava channels, and lava flows. The "coherent intrusive model" incorporates each of these elements and provides a viable explanation for each of their occurences.

References: [1] Okubo, C.H. and Martel, S.J.(1998) *J. Vol. Geotherm. R.,* 86, 1-18 [2] Walker, G.P.L.(1986) *Geology*, 14, 310-313 [3] Walker, G.P.L. (1992) *J. Vol. Geotherm. R.*, 50, 41-54 [4] Rubin, A.M.(1990) *Bull. Vol.,* 52, 302-319 [5] Gudmundsson, A.(1995) *J. Vol. Geotherm. R.,*64, 1-22 [6] Gudmundsson, A.(1998) *JGR.,*103, B4, 7401-7412 [7] Rubin, A.M. and Pollard, D.D.(1987) *US Geol. Surv. Prof. Pap*. 1350, 1449-1470 [8] Gudmundsson, and 2 others (1999) *J. Vol. Geotherm. R.*, 88, 1-13 [9] Pollard, D.D. and 4 others (1983) *Tectonophysics,* 94, 541-584 [10] Mastin, L.G. and Pollard, D.D.(1988) *JGR*, 13221-13235 [11] Rubin, A.M. (1992) *JGR*, 97, B2, 1839-1858 [12] McKenzie, D. and 2 others (1992) *JGR,* 97, E10, 15977-15990 [13] Parfitt, E.A. and Head, J.W. III(1993) *Earth, Moon, and Planets*, 61, 249-281 [14] Grosfils, E.B. and Head, J.W. III (1994) *Geophys. R. Lett.,* 21, 701-704 [15] Ernst, R.E. and 4 others (1995) *Earth-Science Rev.,* 39, 1-58 [16] Mege, D.and 4 others (2000)*LPSC XXXI,* 1854 [17] Wilson, L. and Head, J.W. (2000) *LPSC XXXI*, 1371 [18] Twiss R.J. and Moores E.M.(1992) *Structural Geology* [19] Ackemann, R.V. and 2 others (1999) *J. Struct. Geo.* (submitted).