N94-16381

VENUSIAN 'PANCAKE' DOMES: INSIGHTS FROM TERRESTRIAL VOLUMINOUS SILICIC LAVAS AND THERMAL MODELING.

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The so-called 'pancake' domes, and several other volcanoes on Venus, appear to represent large extrusions of silicic lava. Similar voluminous rhyolite lava flows, often associated with mantle plumes, are known on Earth. Venus' high ambient temperature, and insulation by the dome's brecciated carapace, both act to prolong cooling of a dome's interior, allowing for episodic lava input over an extended period of time. Field relations and aspect ratios of terrestrial voluminous rhyolite lavas imply continuous, non-episodic growth, reflecting tapping of a large volume of dry, anatectic silicic magma. Petrogenetically, the venusian domes may be analogous to chains of small domes on Earth, which represent 'leakage' of evolved material from magma bodies fractionating from much more mafic liquids.

Physical volcanology: The volumes, high aspect ratios, and morphologies of certain lava flows on Venus, especially the pancake domes, imply that these are "unusually large" non-explosive eruptions of silicic magma [1-3]. Even on Earth, large volumes of silicic magma do not always erupt explosively, and rhyolite lava flows of great areal extent and large volume are increasingly being recognized. These units have silica contents ranging from 68 to 77 wt. %, long dimensions usually in excess of 10 km, and areas of generally up to 800 km^2 [4-11]. The volumes of these terrestrial lavas range up to about 200 km^3, while the largest Venus pancake domes are an order of magnitude larger [3] (see Fig. 1).

The beautiful circularity of the Venusian pancake domes contrasts with the shapes of large-volume silicic lavas on Earth. The terrestrial lavas are ovoid to irregular in plan shape [4,5,8,9], due in part to sloping topography, but also to the presence of near-vent tephra rings. Dome-forming rhyolitic eruptions on Earth characteristically begin with explosive activity that results in a ring of tephra concentric to the vent [12]. Such tephra deposits can be a serious impediment to the spreading of even large-volume units. The fissure-fed, 15 km^3 rhyolitic Badlands lava flow of SW Idaho, USA, divided into several separate flow lobes of various sizes as it pushed aside and flowed over and around its earlier-erupted tephra [9,10]. If explosions driven by moderate volatile content are suppressed by Venus' high atmospheric pressure [13], tephra rings may form only rarely, and the observed circular dome shapes may be a result of this.

The unnamed 175 by 250 km-wide complex of thick flow units between Artemis Chasma and Imdr Regio [2] is very similar in structure and appearance to the Juniper Mtn. Volcanic Center in SW Idaho, though the latter is smaller by half an order of magnitude. Shield-shaped Juniper Mtn. was originally interpreted as a construct of ignimbrite units [14,15], but further fieldwork has shown it to be a 20 by 30 km-wide stack of overlapping rhyolite lavas, presumably fed from a central vent, sitting atop a broad, 35 by 50 km-wide plateau of thicker lava units [16].

Thermal modeling: Many geologists familiar with small, thick silicic domes such as those of the Mono and Inyo Craters, E California, USA, assume that terrestrial rhyolite lava flows are constrained to be small because of the lava's high viscosity. While a high viscosity is certainly an impediment to flow movement, it must be evaluated in relation to the lava flow's heat budget [11]. Several factors combine to keep a large rhyolite lava hot and able to flow: 1) the pumiceous and brecciated top and base of the lava flow provide extremely efficient insulation; 2) the unit's thickness and release of latent heat helps keep its interior near the extrusion temperature for an extended period of time; and 3) the unit's substantial thickness at the vent provides a large horizontal force for sustaining flow advance.

While Venus' high atmospheric pressure will suppress vesiculation [13] and thus prevent formation of a thick pumiceous layer at the surface of a silicic lava flow, the lava's carapace will nonetheless be a jumble of welded and loose, boulder- to ash-sized debris [10,11] that will also insulate the flow. Under Venus' ambient surface conditions, cooling (from perhaps 950 °C) to solidus temperature (~700 °C) of the interior of an average pancake dome 600 m thick will require on the order of 1000 years [16]. During such a long period of potential activity, these domes could advance appreciable distances even if spreading was very slow, and they could be formed

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by many episodes of endogenous growth -- even decades apart -- once a sufficient lava volume (probably as little as 2-5 km^3) had been extruded.

That individual pancake domes may have been emplaced by such episodic growth is implied by the positive correlation of their aspect ratios (height/diameter) and volumes [17]. This same relation is shown by the Mt. St. Helens dome, emplaced in 16 episodes over six years [18], and by episodically emplaced domes of polyethylene glycol wax extruded under cold water in the laboratory [17]. In contrast, populations of terrestrial large-volume silicic lavas show a negative correlation of aspect ratio and volume -- as lava flow volume increases, aspect ratios decrease (Fig. 1). Few voluminous terrestrial lavas are sufficiently exposed to be studied for evidence of episodic emplacement, but the Badlands lava flow is an exception [9,10]. In the well-exposed vent area of the Badlands flow, long, coherent flow foliations outline the vent and parallel the flow margins, implying that extrusion from the fissure vent was uninterrupted, not episodic [16].

Petrogenesis: Many voluminous rhyolite lavas on Earth are not associated with caldera structures, but seem to be the result of magmatic systems that differ from the crystal fractionation-dominated caldera-type systems to which most small-volume rhyolite domes and flows are related. In SW Idaho, silicic magma bodies were originally formed by melting of dry crustal rock over the Yellowstone Hotspot plume [4,15], but these silicic magmas evolved further by fractional crystallization processes, as indicated by chemical analyses of the lavas [16]. Preliminary melt inclusion data indicate that the SW Idaho lavas had pre-eruptive dissolved water contents of only about 3 wt. % [19], which may explain why they did not erupt as ignimbrites.

Available evidence indicates that terrestrial voluminous rhyolite lavas extruded in a continuous manner from large bodies of 'dry' rhyolitic magma. If the venusian pancake domes are indeed silicic and were formed by episodic growth, they may be the products of huge basaltic magmatic systems from which relatively small volumes of silicic differentiates could repeatedly 'leak out', as quickly as they were generated. At least in terms of magma genesis and eruption, then, the Venus domes might in fact be more analogous to terrestrial small-volume domes than to the voluminous rhyolite lavas that are most nearly their own size.

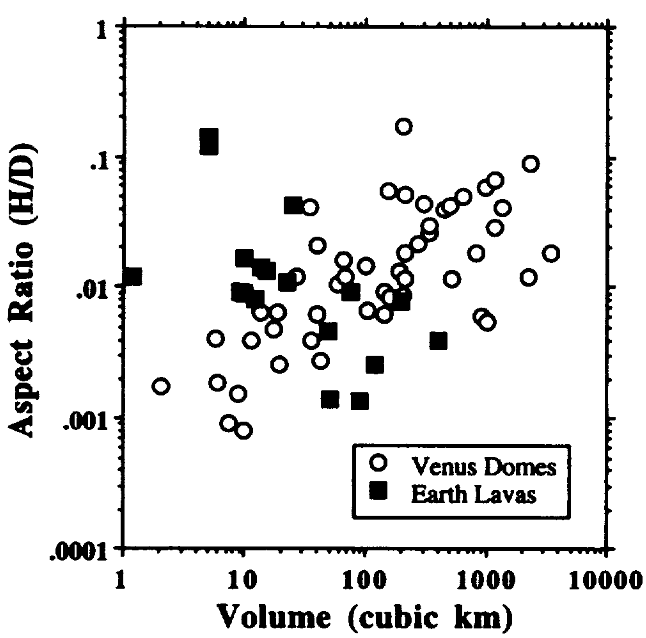

Figure 1. Aspect ratio (height/diameter) as a function of volume for Venus 'pancake' domes with the most accurate height determinations [1,3,17] and for some voluminous rhyolite lava flows on Earth [5-9,16,20]. For the terrestrial data, 'diameter' is that for a circle with an area equal to that of the lava flow.

References: [1] McKenzie D., Ford P.G., Liu F. and Pettengill G.H. (1992) *JGR*, **97**:15967-15976. [2] Moore H.J., Plaut J.J., Schenk P.M. and Head J.W. (1992) *JGR*, **97**:13479-13493. [3] Pavri B., Head J.W. III, Klose K.B. and Wilson L. (1992) *JGR*, **97**: 13445-13478. [4] Bonnichsen B. (1982) In: *Idaho Bur. Mines Geol. Bull.* **26**:283-320. [5] Bonnichsen B. and Kauffman D.F. (1987) In: *GSA Spec. Pap.* **212**:119-145. [6] Cas R. (1978) *GSA Bull.*, **89**:1708-1714. [7] Christiansen R.L. and Hildreth W. (1988) *GSA Abs. Prog., Rocky Mtn. Sec.* **20**:409. [8] Henry C.D. et al. (1988) *Geology*, **16**:509-512. [9] Manley C.R. (1990) *GSA Abs. Prog.*, **22**:A290 [10] Manley C.R. (1992) *Eos - Trans. AGU*, **73**:636. [11] Manley C.R. (1992) *JVGR*, **53** (in press). [12] Williams H. and McBirney A.R. (1979) *Volcanology*, Freeman, Cooper, San Francisco. [13] Head J.W. III and Wilson L. (1986) *JGR*, **91**:9407-9446. [14] Ekren E.B., McIntyre D.H., Bennett E.H. and Malde H.E. (1981) *USGS Map* **I-256**, scale 1:125,000. [15] Ekren E.B., McIntyre D.H. and Bennett E.H. (1984) *USGS Prof. Pap.* **1272**. [16] Manley C.R. - unpublished data. [17] Fink J.H., Bridges N.T. and Grimm R.E. (1993) *GRL* (in press). [18] Swanson D.A. and Holcomb R.T. (1990) In: *IAVCEI Proc. Volcan.*, **2**:1-24. [19] Manley C.R. and Hervig R.L. (1991) *Eos - Trans. AGU*, **72**:567. [20] Guest J.E. and Sanchez J. (1969) *BV*, **33**:778-790.