COLLAPSED "LAVA" TUBES ON ARIEL? David. A. Rothery, Department of Earth Sciences, The Open University, Milton Keynes MK7 6AA, England

Ariel is the densest satellite of Uranus (1.65 ± 0.30 g cm^{-3}) and has a diameter of about 1160 km (1). Its bulk composition is probably about half silicate and half ice. It is not clear whether Ariel's thermal history includes substantial melting of the interior, which would have allowed the silicate matter to sink inwards to form a rocky core, or whether the silicate material remains disseminated throughout most of its bulk. The ice is likely to be a solid solution of H_2O and NH_3, with H_2O being considerably more abundant and there is an unknown amount of CH_4 and/or CO held within the ice lattice as a clathrate (2).

During its 1986 flyby, Voyager-2 produced useful images over about one-third of Ariel's surface. As described by Plescia (3) these revealed an old cratered terrain broken by apparently tensional features. Polygons of cratered terrain are separated either by ridged terrain (also heavily cratered) or by a lightly-cratered plains unit, that fills a system of branching graben-like features (chasmata) and sometimes spills out beyond their ends. This plains unit has been regarded as being the result of a flow process since it was first described (1), but the mechanism of flow emplacement remains debatable.

Where it lies within a graben, the plains unit often contains a narrow (ca 2-3 km wide) linear or sinuous medial trough, notably Leprechaun Vallis and Sprite Vallis (Fig.1), or sometimes a medial ridge. These have been variously interpreted as faults/fractures due to the extensional effects of doming (1,4), fissures that fed the flows that constitute the plains unit (1,3,5,6) or junctions between two fissure-fed flows (5). Of all the planetary bodies, only the Earth has been demonstrated to have volcanic fissures of comparible length (>100 km), namely the oceanic spreading axes. I propose here as an alternative that these troughs may be the remains of tube systems through which the molten material flowed, and that this is not inconsistent with the convex photometric profiles reported by Jankowski and Squyres (5). Major tube-fed basalt flows are well-known on the Moon, at a not greatly dissimilar scale bearing in mind the reduced gravity on Ariel; Hadley Rille has an average width of 1.2 km (7), comparible to many other sinuous rilles. Similar, but narrower, features have been documented on the Earth and Mars. Perhaps the closest morphometric analogue to a chasma-vallis pair on Ariel is the Alpine Valley on the Moon, which has a ~600 m wide rectilinear rille running the length of its lava-filled floor. This particular rille has been variously interpreted (8,9) as a tube and/or channel system or as a late-stage tension fracture, which is not particularly helpful in trying to understand events on Ariel.

On Ariel the most likely "magma" is a eutectic melt of composition $2H_2O.NH_3$, that would be produced by partial-melting of ammonia-water ice at 176 K. Such a melt is thought to have a viscosity of about 10^2 P (10, 11), and once formed, being less dense than the coexisting solid, it would migrate upwards along channels between ice grains. Stephenson (11) describes how such a melt, if once generated within a body such as Ariel, could become erupted at the surface. He points out that lower gravity would compensate for lower viscosity, making such a flow analagous to molten basalt on a terrestrial planet. I suggest that rapid quenching of the flow surface at Ariel's ambient surface temperature of around 60 K could form a thermally insulating layer of low-conductivity NH_3-H_2O glass. Thus it appears that we have all the requirements for a tube-fed flow system. Many tubes on the moon collapsed following withdrawal of the melt, to produce the sinuous rilles; similar collapse could have produced the medial troughs found on Ariel. The medial ridges on Ariel could be tubes that never drained and where contraction (due to degassing?) or subsidence of the rest of the flow surface left the filled tube as a positive feature.

In the absence of high-resolution images, particularly of the putative source regions of Ariel's medial grooves, it may not be possible to prove or disprove this theory with the existing data. However, efforts should made to study of the surface slopes of the graben-bounded plains units of Ariel to assess whether individual medial grooves consistently head downhill in the same direction. An important consequence of the positive identification of tubes would be that this would rule out alternative mechanisms for flooding the rifts; by ice mobilized by trace amounts of intergranular CH_4, N_2 or CO fluid proposed by Stevenson and Lunine (12) and solid-state creep proposed by Jankowski and Squyres (5), because with viscosities in excess of 10^{12} P and no melt/glass relationship there is apparently no way in which tubes could develop. The identification of tubes would also put limits on the amount of supercooling or contamination of the melt, as these processes can increase the viscosity of the melt by several orders of magnitude (13, 14) to a level where tubes are unlikely.

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Figure 1. Image about 350 km across, showing a possible "lava" tube, Sprite Vallis, running along the centre of Brownie Chasma. (Voyager-2 image 26845.39)