Charon's Smooth Plains

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We have previously described the geology of Charon's smooth plains [1] known as Vulcan Planum (this place-name and others in this abstract are informal), which has been hypothesized to have been resurfaced by a large cryo-flow. Other large icy bodies in the solar system for which resurfacing is observed either have limited areas of resurfacing, later activity that overprints the resurfacing, or just poor data resolution, such that developing and then testing hypotheses are difficult. We think that Charon's global expansion [2] and the subsequent resurfacing were both the result of the progressive freezing of a subsurface ocean. This sequence of events provided a surface that records this geologic resurfacing, without overprinting by other processes.

We hypothesize that the resurfacing of the smooth plains is not the result of a singular eruptive or effusive center from which cryoflows spread out across the more than 400,000 km^2 of Vulcan Planum in a manner similar to large basaltic flows on the Earth. Instead, we hypothesize that the resurfacing was the result of crustal blocks foundering, and the buoyant, viscous cryo material under those blocks rising up and spreading out [3]. In this manner, there would be no singular effusive center, but the sources of the smooth plains material would be in many places across Vulcan, and as the material enveloped the foundering blocks, it would create a smooth, extensive plains unit.

Rheology of the flow: We interpret the lobate, rounded features on Vulcan Planum to be the result of flow emplacement of the surface. The lobate margins, which encircle the mountains, appear to be the result of viscous flow that has encountered an obstacle. The depressed margins along the Oz Terra scarps also imply a viscous flow that was flowing towards the boundary scarps.

To derive a viscosity, we assume that the flow was emplaced in a single event, that the viscosity was high enough that inertia can be neglected, and that the pre-emplacement surface was horizontal. Under these assumptions, the emplaced fluid spreads under its own weight and known equations can be used to analyze its motion. The biggest uncertainty associated with these equations is determining the duration of flow.

We used four potential fluids in our calculations: water, ammonia-water, N_2, and CO. The viscosities derived assuming radiative cooling ($\sim 10^{13}$ - 10^{15} Pa s) are much higher than likely liquid or slush viscosities, but similar to the viscosities derived by Jankowski and Squyres [4] for flows on Ariel. If we assume that these flows are Bingham rheology cryo-flows, we can use topographic profiles to estimate the Bingham yield stress. When we do, we find yield strengths from 8.3×10^3 to 4.6×10^4 Pa. These are similar to the yield strengths reported by Melosh and Janes [5] for flows on Ariel, and are in the range of yield strengths for terrestrial silicate lavas. Although it is difficult to distinguish between solid-state extruded flows and a viscous mixture of liquid and crystals [6], it seems that characterizing the features we see on Vulcan as the result of cryo-flow is reasonable.

Foundered Crustal Blocks: The transition between the tectonic structures in Oz Terra and Vulcan Planum might appear to be abrupt, but we propose that these two terrains are natural end-members given the tectonics and chemistry at play on early Charon. The tilted surfaces of the crustal blocks in Oz that directly border Vulcan represent a point on the continuum between Oz Terra crustal blocks that are not tilted, just translated away from one another, and the blocks that we think foundered, sunk, and were covered over by Vulcan Planum. The isolated massifs in Vulcan would in this case be the tips of such tilted polygonal crustal blocks, which stand above the plains like kipukas or nunataks.

The needed density inversion could have been facilitated by the presence of NH_3 (ammonia) [7, 8]. At NH_3 concentrations above $\sim$26% by mass, a fluid water-NH_3 mixture has a density less than water ice at the very cold temperatures assumed for Charon. With this information, we assume that the ancient surface of Charon, radiating to space, would freeze first, preferentially freezing water out of the solution, enriching the remaining 'ocean' in NH_3 as freezing progressed [7]. This process would leave a mostly-water-ice lithosphere overlying a water-NH_3 ocean, and would also concentrate NH_3 in that ocean, even from relatively small bulk amounts. This arrangement sets up a density inversion so that when the crust expands and breaks up, the less-dense mostly-water-ice lithospheric blocks sink into the water-NH_3 ocean, which wells up, resurfaces the area and then proceeds to freeze. This new surface is rich in NH_3 but photolysis and proton bombardment act to remove it from the surface, making its abundance undetectable by New Horizons spectrometers.

References: **[1]** Beyer et al. *LPSC*. Vol. 48. 2017, p. 2679. **[2]** Beyer et al. *Icarus* 287 (2017), pp. 161–174. **[3]** Schenk et al. *Icarus* in review (2018). **[4]** Jankowski and Squyres. *Science* 241 (1988), pp. 1322–1325. **[5]** Melosh and Janes. *Science* 245 (1989), pp. 195–196. **[6]** P. M. Schenk. *Journal of Geophysical Research* 96 (1991), pp. 1887–1906. **[7]** Kargel. *Icarus* 100 (1992), pp. 556–574. **[8]** Grundy et al. *Science* 351.6279 (2016).